Very truly yours
James B. Francis

President of the Boston Society of Civil Engineers in 1874.

JOURNAL

OF THE

Association of Engineering Societies.

Boston.	Cleveland.	Minneapolis.	St. Louis.
Chicago.	Kansas City.	Montana.	St. Paul.

CONTENTS AND INDEX

OF

PAPERS AND PROCEEDINGS.

VOLUME XIII.

January, 1894, to December, 1894.

PUBLISHED BY

THE BOARD OF MANAGERS OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

John C. Trautwine, Jr., *Secretary*, 419 Locust Street, Philadelphia.

CONTENTS.

VOL. XIII, 1894.

For alphabetical index, see page ix.

No. 1. JANUARY.

No. 2. FEBRUARY.

No. 3. MARCH.

No. 4. APRIL.

No. 5. MAY.

No. 12. DECEMBER.

INDEX.

VOL. XIII, 1894.

The twelve numbers were dated as follows:

No. 1, January.	No. 4, April,	No. 7, July,	No. 10, October.
No. 2, February.	No. 5, May,	No. 8, August,	No. 11, November.
No. 3, March.	No. 6, June,	No. 9, September,	No. 12, December.

ABBREVIATIONS.—P = Paper; D = Discussion; I = Illustrated; C = Contribution Box (paragraphs); L = Library (book reviews).

Names of authors of papers, etc., are printed in *italics*.

ASSOCIATION

OF

ENGINEERING SOCIETIES.

Organized 1881.

VOL. XIII. JANUARY, 1894. No. 1.

This Association is not responsible for the subject-matter contributed by any Society or for the statements or opinions of members of the Societies.

JAMES BICHENO FRANCIS.

A MEMOIR.

BY DESMOND FITZ GERALD, JOSEPH P. DAVIS AND JOHN R. FREEMAN, COMMITTEE OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read September 20, 1893.]

ON September 18, 1892, the Boston Society of Civil Engineers lost its most honored member, and the profession of Engineering one of its brightest lights.

Many of our members who knew Mr. Francis in his later years, and when fame had already crowned his long and busy life, may, perhaps, be unfamiliar with the successive steps in his career.

We can, in this memoir, glance but briefly at the record of this long and exceptionally useful life, which closed in its seventy-eighth year.

James B. Francis was born at Southleigh, Oxfordshire, England, May 18, 1815. The period, when his boyhood days were closing and his working days beginning, found the railway just springing into existence and absorbing the best engineering talent of the time. In 1825 the Stockton and Darlington Railway had proved the capabilities of the system, and in the year 1829, just as Stephenson's "Rocket" was foreshadowing the possibilities of the locomotive, Mr. Francis began his engineering career at the early age of fourteen. His father was superintendent of one of the early short railroads in the south of Wales, and the son quite naturally became his assistant on the construction of some

harbor works connected with that road. Two years later, he was employed on the Great Western Canal in Devonshire and Somersetshire.

On April 11, 1833, Mr. Francis, attracted hither by the hope of obtaining engineering work, reached New York, and almost immediately found employment on the construction of the Stonington (Conn.) Railroad, under Major George W. Whistler, one of the famous early American engineers. Upon this work Messrs. Julius W. Adams and James P. Kirkwood, each of whom, like Mr. Francis, afterward became presidents of the American Society of Civil Engineers, were then engaged.

Some eight years prior to this time, sundry farms, where Lowell now stands, had been acquired by certain enterprising Boston capitalists who had made a success of manufacturing cotton by water-power at Waltham, and who were seeking a broader field for their operations. They acquired a controlling interest in the old Navigation Canal, chartered in 1792, and, under the corporate name of the Merrimack Manufacturing Company, built a dam across the Merrimack, enlarged the canals, adapted them for water-power, and built a cotton mill. In 1825 they had sold a mill site to the Hamilton Manufacturing Company, which erected its mill and began the manufacture of cotton cloth under the skillful supervision of that most eminent pioneer millwright and textile manufacturer, Samuel Batchelder.

In 1826 the Merrimack Company decided to dispose of the mill sites and water rights not needed for its own purposes, and these were, therefore, transferred back to the older navigation company, The Proprietors of the Locks and Canals on the Merrimack River, whose charter and organization had been kept alive.

Almost at the very beginning of the new developments, the services of Mr. Paul Moody, of the Waltham Mills, who was regarded as one of the very foremost mechanics of the day in the art of cotton manufacture, had been secured, and a large machine-shop had been built. This shop was retained by the Water Power Company for nearly twenty years longer, or until 1845, when it was sold and reorganized as the present well-known Lowell Machine Shop.

In 1833 the Locks and Canals Company, desirous of promoting their machine business in the line of railway work, induced Major Whistler to become their engineer; and Mr. Francis, then eighteen years of age, followed him to Lowell, and entered the service of the Locks and Canals Company's machine shop as a draftsman. Many of the early drawings of Mr. Francis—models of neatness and skill—are still in existence in the archives of these old corporations. Among his first tasks was that of dismembering and measuring a locomotive which had just been built by Stephenson, and brought over from England to serve as a model for the engines of the Boston and Lowell—the earliest

of the New England railroads—and of making full drawings from these measurements.

Mr. Francis' early surroundings, and his association with master-minds like Nathan Appleton, Patrick Jackson, Kirk Boot, the Lowells, the Lawrences, and others of those who laid the foundations for New England's industrial greatness, with engineers like Major Whistler, Charles S. Storrow, Uriah Boyden, and with young companions like William E. Worthen, were such as might well arouse the ambition of any young man.

The Locks and Canals shop never became very largely occupied with locomotive work, and Mr. Francis did but very little of such work, but soon was fully occupied on millwright drafting and designing. In fact, when but nineteen years of age, he was entrusted with much of the responsible design and oversight of the Boot Cotton Mills, then under construction.

Although these early mills were small compared with their mammoth successors of the present day (the average cotton mill then being of 5,000 spindles capacity, in a four-story building, 45 feet wide by 150 feet long), we must remember that precedents were few and that there were no such accumulations of data as safely guide the engineer of to-day. That rare quality, judgment, had often to bear greater responsibility than in the tenfold greater structures of the present.

In 1837, Mr. Francis married Miss Sarah W. Brownell, the daughter of Mr. George Brownell, Superintendent of the Locks and Canals Machine Shop. Mr. Brownell had come to Lowell from the earlier cotton mills at Waltham, and was regarded as one of the foremost men of his times in matters of factory machinery. At about this time Major Whistler resigned his position as engineer to the Machine Shop and water-power interests; and Mr. Francis, at the early age of twenty-two, was appointed engineer. His relation with the Locks and Canals Company, as Chief Engineer and afterward as Consulting Engineer, continued for fifty-five years.

Although Mr. Francis had not had the advantage of an extended education, he early formed the habit of close and unremitting study. His evenings, at this time, were largely devoted to perfecting himself in mathematics and in other sciences connected with his work.

It must be kept in mind that Mr. Francis, though trusted and respected for his faithful work, had not in these earlier years attained the fame which subsequently became his, and so it came that when, three or four years later, it was desired to determine, by the very highest authority, the quantities of water-power drawn by the several mills, a commission for this purpose was appointed, consisting of Major Whistler, James F. Baldwin and Charles S. Storrow, the latter of whom, although

then a young man of but thirty years, was manager of the Boston and Lowell Railroad, had studied in the foremost schools of France, and was doubtless at that time the best educated engineer in America.

The details of the experiments and measurements of water were entrusted chiefly to Mr. Francis, and so well satisfied was Mr. Storrow with his accuracy, judgment and skill, that he advised the managers of the Company to rely on him for such work as they might need in future.

In 1845, at the beginning of the development of the water-power where Lawrence now stands, Mr. Storrow tendered to Mr. Francis, and urged him to accept, the position of resident engineer on this work—the largest power development which had, up to that time, ever been attempted, and one which involved many difficulties and great responsibilities.

The Locks and Canals Company was fast awakening to the rare capabilities of young Mr. Francis, and promptly offered such inducements as made him content to continue in its service. In 1845, he was made "Agent" or general manager of the Company as well as its engineer. In the same year "The Proprietors of the Locks and Canals on the Merrimack River" sold the machine construction branch of their business to a new corporation—the Lowell Machine Shop, and other readjustments of the property rights were made, by which the principal manufacturing corporations became themselves proprietors of the stock of the Locks and Canals Company, each in proportion to its water-power rights, and from this time on, for upward of forty years, Mr. Francis not only cared for the dam, the canals and the water-power, but also acted as consulting engineer to these factories, which became among the largest and most important in the world.

Few men have had such opportunities, and few have availed themselves of such opportunities, as opened to Mr. Francis, for in the early years of his responsibility, the factory system and the textile industries were developing with a vigor scarcely equalled, except in the marvelous electrical developments of the past few years. Here at Lowell were manufacturing interests which were constantly enlarging their plants or their facilities for production, and to all of these interests he was practically consulting engineer.

We transcribe from a statement by Mr. Hiram F. Mills, his assistant of thirty-seven years ago: "Mr. Francis' habits of thought were methodical. He was often asked by the directors of his company or by the agents of the manufacturing companies, questions concerning their peculiar departments of business, in such variety that no one who was not in the special business could be expected to give advice; but he, taking the question definitely in mind, went to his office and began a page of his calculation book with 'Mr.—— wants to know,' so and so.

He would then write out in full whatever of value he could find published upon that subject, together with his conclusions, and when he met his questioner again, he was ready to discuss the subject in all its bearings and to give intelligent advice. From this habit of thoroughly investigating the subjects that came before him and writing out his data and conclusions in form convenient for reference, he came to be rightly acknowledged as an authority upon many and various subjects."

The growing size of the factories, the magnificent water-powers available along the Merrimack, and the limitations of the high and cumbrous breast water-wheels, had directed attention to the reaction wheels in use in France; and in 1844 Uriah A. Boyden, the life-long friend and early counsellor of Mr. Francis in hydraulic matters, had planned and built his first water-wheel. Soon afterward we find Mr. Francis engaged in further experiments and tests upon turbines of Mr. Boyden's design and upon designs of his own.

In his remarkable treatise, "The Lowell Hydraulic Experiments," a contribution to hydraulic science which has scarcely been surpassed, either before or since its appearance, Mr. Francis gives an account of certain of his experiments. The completeness of this work, the precision with which the experiments were conducted and recorded, the painstaking care bestowed upon their collation and presentation, and the mature scientific insight, worthy of the very foremost physicists, and manifest in every page, would reflect credit upon the most experienced author; yet Mr. Francis, at the time of the publication of this great work, was a young and self-taught and hard-working engineer. Many of our members have walked along the magnificent Northern Canal, with its bold and massive river wall; but few, perhaps, have realized that this and the attendant works, costing over half a million dollars, were designed and constructed by a young man thirty-one years of age.

We may recall a notable instance to illustrate the prudence of this young engineer and his steadfast courage in his own convictions. When designing the head-work for this new canal and determining the height to which it should be built, he sought with great diligence for records of former floods along the Merrimack, and found, in the records or traditions of 1785, a flood higher than any since known, a flood which, after allowing for the obstruction since caused by the erection of the dam, would, if reproduced, rise to the very top of the guard locks of the old canal and possibly sweep with great damage down through the heart of the city. He therefore caused a new barrier to be built, a short distance below the old head gates, while for shutting off the canal itself he arranged a massive gate, 27 feet wide by 25 feet high, which hung suspended in the air over the lock. This was con-

structed in 1850, and as its need was beyond the comprehension of most of those who saw it, it came to be often referred to as "Francis' folly." Its vindication came with remarkable promptness. Only two years later the freshet of sixty-five years before was reproduced, and, indeed, was exceeded. Rapidly the water rose to the topmost limit of the earlier barriers and began to work its way around them. The strong iron link which upheld the gate was cut, and the gate dropped and held back the flood, which continued to increase for about twenty-two hours afterward, and rose to a height 2.23 feet greater than that at which it worked over and around the old barrier.

Most of our members have often heard this story, and have furthermore been told how the citizens tried to atone for their former lack of appreciation by presenting Mr. Francis with a silver service "in token of their admiration of his foresight and sagacity" in constructing this gate. Without it, as was stated in the Boston *Advertiser* a few days after the flood, "every vestige of the old guard gates would have been carried away, and a mighty and uncontrollable river would have swept through the heart of Lowell, destroying everything in its course."

The preservation of timber from decay early engaged the attention of Mr. Francis, and at the request of the Lowell Mills he visited England some forty-four years ago, in order to study the processes in use there. On his return a plant for kyanizing was erected under his supervision, and this has been maintained and operated to the present time. Apparatus for burnettizing timber was subsequently erected by him, but its use was discontinued after careful practical tests.

During many years an agreement for mutual protection against fire loss was in force among the Lowell factories. Under this agreement it was sought not only to divide and share any accidental loss, but also to prevent, so far as might be, the possibility of a serious conflagration. The execution of the precautionary works was left to the care and skill of Mr. Francis. A generous and well planned system of supplying water for fire purposes was installed, years before anything equally complete was to be found elsewhere. That this generous system and the prudent organization of watchman service were not in vain, may be inferred from the fact that notwithstanding the great concentration of values, the tallness of the buildings, the extent of the floor areas and the combustible nature of the stock, the record of the past forty years is said to show, for the Lowell Mills, a fire loss scarcely one-half so great as among the cotton factories of New England as a whole.

In many ways Mr. Francis' example was an education and a blessing to his contemporaries and to his followers—in none more so

than in holding close to experiment as a guide. In designs and in engineering estimates, it was with him a fundamental rule to hold closely to experiment, and to beware of carrying the application of an empirical rule far beyond the limits of the experiments upon which it was founded. Among scores of illustrations of this which might be taken from Mr. Francis' practice, we may notice his experiments on large cast-iron beams. Rather than trust, in an important case, wholly to the remarkable experiments made three years before by Eaton Hodgkinson, with English iron and with sections generally smaller than those in question, Mr. Francis had cast from American iron girders of about the size and shape desired (19 feet long by 15 inches deep), and tested them to the point of rupture—35 and 57 tons load respectively. These were probably the earliest tests on large girders of American iron.

Mr. Francis' zeal for experiment upon a scale commensurate with the actual work in hand, is well illustrated also by his world-renowned researches upon the flow of water over weirs and upon flow in channels as determined by floats, by his methods of testing turbines, and by his rules for proportioning them.

Mr. Francis' chief publication, "The Lowell Hydraulic Experiments," appeared in its first edition in 1855. This volume made Mr. Francis' name respected by hydraulic engineers all over the world. It is indeed a wonderful record of a remarkable series of experiments made at Lowell in connection with the development of the water-power and its distribution among the mills, and we believe that even to this day no book has been published to which the young experimenter in engineering can more profitably turn for an illustration of the scientific method.

It is needless to say that as the years passed and as Mr. Francis accumulated a vast store of knowledge and experience, his counsel was in constant demand both as an expert in water cases and as a consulting engineer.

The breadth and depth of the mark which our great engineer left upon the work of the times is nowhere more strikingly illustrated than in the list appended to the memoir published by the American Society of Civil Engineers, in which are enumerated his professional papers on file in the office of the Locks and Canals; and this list, it must be remembered, refers almost wholly to Mr. Francis' outside or consulting work, and gives no idea of the extent of his own special investigations connected with the mills at Lowell.

It was not Mr. Francis' ambition or fortune to build to himself monuments in many lofty or imposing structures. It fell to his lot rather to expend his rare judgment, experience and skill, in counseling other

engineers and constructors about the features of special difficulty in their work, or in designing work of his own, which, though none the less important and necessary, went underground and thus made but little show.

Arduous as his duties were, he still found time to write many valuable papers for various learned societies. His contributions to the Transactions of the American Society of Civil Engineers were numerous and always noteworthy. They comprise records of many experiments upon the flow of water, the deflection of beams, and the percolation of water through cement, and reports on the Mill River and Johnstown disasters caused by the giving way of dams. His memoir on the strength of cast-iron pillars was prompted by the fall of the Pemberton Mills at Lawrence, and was read, in 1865, before the American Academy of Arts and Sciences of Boston, a society of which Mr. Francis was for many years a valued member.

Mr. Francis was, in 1848, one of the original members of the Boston Society of Civil Engineers. He became its president in 1874. His residence in Lowell prevented him from attending the meetings regularly, but he always manifested a deep interest in its aims and in its success.

In 1852 he became a member of the American Society of Civil Engineers at its first meeting, and was elected its president in 1880. On April 5, 1892, he was elected honorary member. His sociable and friendly nature led him to attend many of the Annual Conventions of that Society, where he added greatly to the interest of the discussions and to the enjoyment of the excursions and social entertainments, and his absence will nowhere be more keenly felt by his brother engineers than on future occasions of this kind.

Mrs. Francis, who is known to many of our members from her accompanying her husband on these excursions, survives him, as do their four children, George E. Francis, M.D., a prominent physician of Worcester, Mass., Col. James Francis, C.E., the present Chief Engineer of the Locks and Canals Co., Charles Francis, C.E., Engineer of Public Works at Davenport, Iowa, and Mrs. Elizabeth Francis Bennett, of Bay View, Mass.

Among the responsible offices which Mr. Francis found time to fill were those of member of the Legislature and of the City Government of Lowell.

As engineer, as referee, and as expert, Mr. Francis was probably called upon to decide more varied questions of importance than often fall to the lot of any one man to pass upon. This arose largely from the solidity and strength of his character, from that strong common sense for which he was so well known, from his unruffled disposition and his love for the truth.

He was of sturdy build, and, in the later years of his life, of striking and venerable appearance.

No one, even if a stranger, could remain long in Mr. Francis' presence without becoming deeply impressed with the strength of his mental endowments and the genial spirit that guided his every word and deed; and certainly we, as engineers, knowing his wide reputation, his modest appreciation of his own worth, his scholarly attainments, his indefatigable perseverance, and his deep-seated love for the truth, have good reason to hold in highest regard the memory of this man, upon whose like we shall not look again.

AUGUSTUS WOODBURY LOCKE.

A MEMOIR.

By G. A. Kimball, J. W. Ellis and C. A. Allen, Committee of the Boston Society of Civil Engineers.

[Read November 15, 1893.]

Augustus W. Locke was born in the town of Rye, N. H., on the 26th of February, 1846. He received his preliminary education in the schools of that town and attended the Academy at Pittsfield, N. H. In 1861 he enlisted in the U. S. Navy and served until 1863, and then took up the study of engineering. He worked his way, teaching school during a portion of the time, and completed his engineering studies at the Massachusetts Institute of Technology.

In 1867 Mr. Locke was for a time employed on the United States Coast Survey. In 1869 he was appointed assistant upon the Hoosac Tunnel and was stationed at the east end. He was connected with the tunnel until it was completed, and a share of the credit for the accuracy of the alinement is due to his careful and persistent work. After the completion of the tunnel he continued on the engineering staff for a few years, and he was then appointed State Manager of the Hoosac Tunnel, Troy and Greenfield Railroad by Governor Long, in which position he remained until the property was sold by the State to the Fitchburg Railroad Company. The work of Mr. Locke as manager of the State's tunnel and railroad has often been favorably commented upon. The employees showed their appreciation of Mr. Locke by presenting him with a fine gold watch when he retired from the position.

On July 11, 1888, Governor Ames, acting under authority of Chapter 99 of the Resolves of the Massachusetts Legislature for that year, appointed Mr. Locke as one of "three competent and experienced engineers to report to the Legislature upon the subject of the Gradual Abolition of the Crossing of Highways by Railroads at Grade." On the organization of this Board of Engineers Mr. Locke was chosen chairman, and after seven months' faithful and laborious work, the Board presented to the Legislature a report dated January 31, 1889. This report, which bears the marks of his careful and thorough work, gave great impetus to the movement for the abolition of grade crossings in Massachusetts.

In 1891 he opened an office in Boston and associated with him his brother, Mr. Franklin B. Locke. The two brothers gave special atten-

tion to railroad and tunnel work, and at the time of the death of Mr. A. W. Locke had been engaged on several grade crossing problems.

Mr. Locke served upon a commission of engineers to report general plans for the abolition of all grade crossings in Worcester, Mass. The report is dated February 1, 1892, and is considered a very able document.

Mr. Locke served on many commissions appointed by the Superior Court for the abolition of grade crossings. He prepared plans for the City of Northampton for abolishing the grade crossings and continued the engineer in charge of this matter until his death.

In 1892, Mr. Elmer L. Corthell and Mr. Locke reported on the grade crossing problem in Buffalo, N. Y., and the same year he was employed to report a plan for the abolition of grade crossings in the City of Lynn, Mass.

For nearly twenty years he was a resident of North Adams, Mass., and during the last part of his life maintained an office there. He designed the sewerage system and water supply of that town. In 1876 he married Martha P. Perkins, of Hampton, N. H., who, with one son and three daughters, survives him. At his home in North Adams he had many friends and was always ready to help anyone in need. He took a lively interest in the affairs of the town, and served it in many public positions.

Mr. Locke joined our Society, October 18, 1882. He has contributed two papers, the first entitled "Notes upon Engineering Work in Holland," and the second "The Gradual Abolition of Grade Crossings."

Mr. Locke was a person of clear mind and great common sense; he was conservative in all his opinions, a great worker, slow to reach conclusions, but sure to base them upon existing facts and conditions. He was a deep thinker and one who investigated very carefully for himself, and in his own original way, every detail of his proposed plan. He was fair, frank and honest in every way, a man whose word could always be depended upon.

LANDSLIDES.

By David Molitor, Member of the Engineers' Club of St. Louis.

[Read October 18, 1893.]

I. Introductory Remarks.

A landslide, especially if of any great extent, may be classed among the worst of the difficulties which the engineer is called upon to overcome.

The literature of this subject is rather limited, and this is owing, perhaps, to the lamentable fact that engineers on construction rarely give to the profession the benefit of their experience, and seldom go to the expense and trouble of collecting data for publication. It is the author's intention to present, in the following paper, such observations as he was enabled to gather from his experience while engaged on railway construction in Germany during the years 1887–90.

II. Classification of Material.

Under certain conditions, any material, even rock, will slide. In the case of a rocky cliff, all that is necessary in order to preserve equilibrium is a foundation capable of sustaining the weight or vertical load; for stratified rock will stand vertically or even overhang without sliding. In loose material, friction and cohesion of the particles produce equilibrium of the mass on a slope, the inclination of which is proportional to the magnitude of the frictional and cohesive resistances of the material. These conditions are entirely modified by the yielding of the supporting earth or foundation, and a mass may be set in motion by removing the foot of a slope and thus destroying the conditions of equilibrium.

Water, the natural lubricant, invariably diminishes the frictional resistance of the particles of earth or of rock upon each other, while it may or may not increase their cohesion. It is impossible to measure independently the effect of water upon these internal forces, but that effect can be observed in large masses of earth. With only a few exceptions, the natural slope is diminished by the addition of moisture. Clean sand affords one of these exceptions, for here the addition of water increases the natural slope, but it is quite probable that this is the case only with small quantities, such as are commonly used for experimental purposes. Rain and frost exert a merely superficial wearing action on earthwork.

It is the author's intention to consider only those materials which are most liable to dangerous sliding, and to leave it to the good judg-

ment of the engineer to make the proper allowances for such materials as offer more favorable conditions.

Whether in cuts or in fills, or in the ground underlying them, the clays and all their various combinations, as marl, loam, bend, etc., will nearly always cause trouble; and peat, alluvium and soil (humus) are as bad as clay and sometimes worse. Marlstone and indurated clay are often as hard as stone when found in the natural strata, but, on being exposed to the action of air and water, and especially to alternations of heat and frost, they disintegrate and become mud.

A brief sketch of the geological strata, pointing out the more objectionable materials, may assist in warning the engineer against unforeseen dangers.

a. Triassic Period. In the geological subdivisions of strata we find dangerous material as far down as the Triassic Period. The only epoch of this period, however, which comes in question is the *Keuper*, of which the *Upper* Keuper is the worst. Even this is usually good, except for high slopes, exceeding, say, 8 meters.

Foundations on Keuper, when well drained, need cause no anxiety, and slopes of cuts will stand perfectly well, up to a height of 10 meters, when laid out 1½ to 1. Thorough drainage is very important in dealing with this material, which is of a quite granular structure and allows water to penetrate freely into its mass. Like sand, it always appears dry on the surface, and the water which collects in the material is apt to show itself in a very undesirable manner.

b. The Jurassic Period contains some of the most dangerous strata which we have to contend with, and these are especially dangerous when found in a mountainous country, as in the Swiss Alps. All these strata, in their natural state, are very hard, and therefore liable to mislead one who is not familiar with their properties. The clays and marls of this period, though some of them require blasting where they are excavated, possess the peculiarity of absorbing large quantities of water and then disintegrating into a soft, smeary material resembling silt. This is exceedingly dangerous material for fills. A cut may stand well if the slopes are protected by a soil-covering and grown over with grass, to keep off the direct action of air and water. Even then the alluvium, overlying the strata, will invariably slide upon the latter, as the water which penetrates to them softens them and produces sliding surfaces.

The most objectionable material of the Jurassic period is the *Opalinus clay*, which occurs in the *lower oolitic*. The *Turneri clay*, which is found in the *middle Liassic* epoch, resembles the opal clay very closely, both in appearance and in objectionable properties. These two are among the worst materials that the engineer is liable to find. They will be mentioned later, in connection with examples of their behavior.

c. The Cretaceous Period contains only a few strata of marls which are to be feared in earthwork, and they offer no greater difficulties than the above-named clays.

d. The Tertiary Period is composed mainly of clays and marls, all of which possess properties similar to those of the Jurassic period. The methods of treating these in connection with earthwork are identical with those to be mentioned for Opalinus and Turneri clays.

e. The Quarternary Period contains clays which are not as compact in their natural layers as those of the Jurassic, but the latter, when softened by water, become even greater enemies to the engineer.

The historical epoch, of this period, contains mostly alluvium and peat, which will be more fully mentioned later on. It might, however, be well to state, in this connection, that the historical strata, which always form the natural surface, may directly overlie any one of the older strata, as for instance the Jurassic, for the intervening strata may have been removed by either aqueous or volcanic action.

Alluvial earth may range from fair to the very worst material for fills. When it is quite sandy, it may be considered good, provided it is not subjected to the direct washing action of water. Rain-water will flow off or penetrate into it without causing much damage unless a bank be very high and steep and not grown over with grass.

When alluvial earth is argillaceous, or when it contains peat, it becomes very objectionable for engineering purposes. Rain-water will then be retained until the material becomes semi-fluid.

III. Classification of Landslides.

We will classify landslides, with reference to the conditions causing them, in four groups:

a. Those occurring where the slope is too steep to maintain equilibrium of the mass.

b. Those caused by inclination of the natural strata, combined with the lubricating action of water. In this and in the previous case we find a clearly-defined sliding surface.

c. Slides caused by the action of water alone. Here the material is softened to such a degree that it becomes fluid.

d. Where the underground is not capable of supporting the weight of the overlying fill material.

1. Slides belonging to group *a* are usually caused by using, for cuts or fills, a steeper slope than the material will maintain. They may also be caused by the action of a stream in washing away the foot of a slope and leaving the bank to cave.

In the former case, if the material be filled earth, the trouble will show itself after a short time (one to eight months, according to circum-

stances) by a bulging out near the foot of the slope, and a corresponding settlement along the edge of the crown. Usually a separation takes place, and the material at the crown gradually sinks, while the foot moves out, and thus new conditions of equilibrium are established.

The final slope, or in this case the surface of repose, is then not a plane, as is assumed by all the present theories of geostatic pressure, but a curved surface. The only exception is a theory by a French engineer, named Leygue, whose experiments were related in "Annales des ponts et chaussées," 1885, II, pp. 788–1003. The subject will be treated more at length in Part V of this paper.

The remedy for such slides is the very simple one of reducing the slope sufficiently to establish equilibrium. This applies also to cuts through the natural strata, except that the indications of excessive slopes are somewhat different from those noticeable on loosely filled earth.

The earth of natural strata possesses a certain cohesion, which will, for a time only, maintain equilibrium of the material under a very steep slope. Gradually, this cohesive force is overcome, and the surplus material separates from the slope (usually in large masses) and slides down to the foot. The cracks, which first appear on the natural surface, assist greatly in causing the slide, by allowing water to penetrate into the mass and aid in producing motion. In examining slides of this class, care must be taken not to attribute them to the action of water alone.

In all these cases it is advisable not to employ retaining walls if it is at all possible to cut the material down to a natural slope. This is usually the best and cheapest method to follow.

For caving banks, where the footing is washed away and the slope becomes too steep, the only cure is, of course, a shore protection in form of a paving, revetment or wall.

It should also be remembered that the experimental angles of repose given by the authorities, are, as a rule, determined by experiments upon small masses, and that for large quantities of earth, as they occur in a railroad embankment, such data are inapplicable. The author of the present paper has found, in many cases on construction work, that the same material, filled to different heights, acquires different angles of repose, so that the actual surface for the equilibrium of earth is not a plane, but a curved surface. A more detailed reference to this fact will be made in Part V of this paper.

2. In mountainous countries, where the geological strata have been disturbed by volcanic action and have been thrown into every variety of inclination, it is quite common to find slides belonging to the second class. Especially a side hill cut is very apt to remove the footing of several strata, which then slide upon the inclined surface of some underlying stratum.

When motion has once taken place, such a sliding surface becomes quite smooth without necessarily being wet; but any rainfall will, of course, assist in producing motion.

The only means for overcoming this difficulty is the removal of all the sliding material, or the replacing of the lost footing by a retaining wall or other structure offering an equivalent resistance.

Slides of this form are very dangerous, for they usually set in motion very large masses, sometimes a whole mountain side. Nothing can here be accomplished by drainage, and the best way out of the difficulty is by changing the location of the work.

3. Slides similar to those caused by the natural slope of strata, are often produced by subterraneous springs, or by strata carrying water. In this case, however, the slope of the strata will not necessarily indicate the direction of the motion, for this will depend upon the slope of the surface. The presence of water in the cracks and the wet condition of the material, usually give a clue to the cause.

These slides are usually local, and can often be prevented by careful examination of the ground and by timely application of proper drainage. They occur most frequently in the slopes of cuts, though we often find cases where springs or other water ways are cut off by the weight of an overlying embankment, and where the water thus accumulating produces a slide. In all such cases the cause must be carefully located and the water drained off by canals or culverts, or by drainage ditches.

For slides in the slopes of railroad cuts, it may at times be more economical to carry off the materials which may obstruct our traffic, unless the property adjoining the slope is too valuable. Should this be the case, the slope must be maintained by cutting a succession of vertical slots or passages in the side of the slope (see Plate 1, Fig. 1). Such passages should be made from 1 to 2 meters in width, and placed at intervals of from 10 to 40 meters, according to circumstances. They should be located in the wet places. They should then be filled with rip-rap (or one-man stones) to the surface of the slope. The water will drain off through these passages, and the stones will act as a buttress to hold up the slope.

This is a very efficient method, and, after a little experience with it, the engineer will become able to deal successfully with what may at first seem a very difficult case.

The natural ground, underlying embankments, should always be carefully examined before material is filled upon it, as many accidents can be avoided by a little drainage.

4. We pass now to the last subdivision of slides, viz.: those caused by a giving way of the underground, owing to the insufficiency of its supporting power.

In any swampy locality, or where peat is found, we are liable to failures of this class. When the ground is level there need be little apprehension, for the soft material will simply be displaced by the filled material, and all that is necessary is to continue filling until sufficient ground has been displaced and the necessary support afforded. When, however, the natural surface is inclined, the difficulties are vastly increased. The fill will then slide downward with the displaced material, and it becomes necessary to resist this downward tendency in addition to displacing the soft material underlying the embankment.

When the underground is peat, varying from 1 to 10 meters in thickness, it is often advisable to excavate the peat before beginning to fill. On level ground it is usually as well to displace the peat by the weight of the fill, though a fill thus made will be subject to severe settlements for some time.

A cut through peat may be maintained by first filling in sand on both sides of the portion to be excavated. Peat has the property of allowing sand (especially wet sand) to penetrate into its structure to such an extent that it ceases to flow. Slopes will stand fairly well when such preparations have been previously made. This method has been successfully applied to the cuts of the North Sea Canal now under construction.

When the surface is inclined, it is well to drain the ground before filling upon it. This can best be done by a drainage ditch carried along the upper side and parallel to the line of the embankment. Another ditch should then be dug at right angles to the former, and from its lowest point, so as to carry-off all water so collected.

These ditches should be of sufficient depth to cut off all springs and porous substrata, and should be filled with rip-rap. This will usually prevent subsequent failures.

Another method, less certain but equally expensive, consists in excavating a foot at the lower base of the embankment, which foot is then filled with stone. This, however, does not drain the whole base of a fill, but only the lower foot, and we are thus forced to place greater dependence upon its supporting properties. This method, therefore, applies better to cases where poor filling material is used than to the present one.

Should the first preparations prove insufficient, resort may be had to filling up, on the lower side of the already completed embankment, sufficiently to prevent the underground from flowing out. This method is called counter-weighting.

IV. Examples.

It may be less expensive to change the location of a railroad section, even though this may involve some sacrifice of work already

completed, than to remedy a slide. A slide is always a costly matter, and it is well to abandon a site involving one if a more suitable location can be found.

In many instances, however, slides do not appear until the work has advanced to such a stage that a change of location is out of the question. Or it may be that in consequence of legal requirements, of the expense of acquiring property, or of natural causes peculiar to a locality, the site of the work will not admit of change, so that the engineer is compelled to carry out his project on the lines laid down, regardless of the cost. He must then decide upon the most expedient method of accomplishing the desired end.

We will, therefore, take up a series of examples which may aid in suggesting the manner of overcoming these obstacles. The question of necessity, as we have seen, must be decided entirely by the conditions of each case.

The examples chosen may be regarded as more or less typical, and as involving all the questions likely to come up in this class of work. They will follow in the order of the above classification.

Class A.

SLIDES WHERE THE SLOPE IS TOO STEEP TO MAINTAIN THE EQUILIBRIUM OF THE MASS.

Plate 1, *Fig.* 1. This slide, on the Paris, Lyons and Mediterranean Railroad, was undoubtedly due to the adoption of a slope too steep for the clay of which the embankment was made. This clay, according to the author's experience, will not stand 1½ to 1 for a height exceeding 5 meters.

The irregular dotted lines in section *A B* show the manner in which the material slid, seeking a slope which would satisfy the conditions of equilibrium. For reasons not known to the writer, it was preferred to restore the original slopes instead of widening out the base and reducing the slopes to say 2: 1, which would, in all probability, have sufficed.

The method adopted consists in cutting passages in the slopes at intervals of 15 to 20 meters, as shown on the plan and by the bold dotted curves in section *a b*. These passages, the upper portions of which are, of course, steeper than the original slope, are temporarily maintained by wooden planking and afterwards filled in with rip-rap. In slides of this class it is not necessary to carry these passages down to the original surface, but they should go at least below the sliding surface and afford some means for drainage. In the present case a culvert or opening is left for this purpose.

These stone passages or ribs are sometimes connected by arches, about 1 meter thick, which assist in supporting and draining the intervening earth. The arches are not very serviceable on embankment slopes and might as well be omitted. They are of value, not as supporting arches, but only as drainage ditches, and in this latter capacity they would render better service in the slopes of a wet cutting than in those of an embankment.

Plate 1, *Fig.* 3, shows a typical slide belonging to this class. The material (Opalinus clay) will not permanently stand a slope of 1 : 1 for a greater height than about 2 meters, and the present height of 7 meters would require a slope of at least 2 : 1, as will be shown in Part V. In the present case the embankment was made simply as a deposit for superfluous material, and hence, after the slide, the slope was only graded down to about 2 : 1 and sown over with grass. It has maintained this slope for over three years without showing any signs of farther movement. It would, however, have been advisable to destroy to some extent the sliding surface, which was very smooth, as this might have produced further trouble had the embankment been used for traffic.

Class B.

SLIDES CAUSED BY THE NATURAL INCLINATION OF STRATA.

Plate 1, *Fig.* 2, shows the cross-section of a slide which occurred on the Nordhausen-Wetzlar Railroad, Germany, in the summer of 1877.

The cut was 285 meters long and had a maximum depth of 22.8 meters, with an estimated volume of 131,652 cubic meters, assuming slopes of 1½ to 1.

The material consisted of layers of compact sandstone, separated by layers of clay varying from 0.10 to 0.5 meters in thickness. These strata were inclined about 3 : 1 in the direction of the surface. At the time of excavating this cut, no springs were noticeable, and no alarming amount of water was ever found, except what came from sudden showers.

The excavation was conducted on the " English plan," with a stulm driven lengthwise through the cut at grade, and loading cars from overhead. The first signs of motion were noticed while this work was in progress, during the summer of 1877, and at the same time the surface, for some distance back, showed depressions and distinct breaks. A ditch (*a*) was maintained above the sliding material to prevent rain from entering the breaks. The section in Fig. 2, Plate 1, shows the condition of the cut in May, 1879.

It was decided to put in a masonry wall at the foot of the slope and to continue the excavation as this work progressed.

A packing of rip-rap was put in behind the wall, with occasional branches extending into the right-hand slope to provide for the proper drainage.

The work progressed so that it was possible to open the road for traffic in August, 1879, and the method has proved successful, although some extensive repairs have been made since then.

The wall at the foot of the slope serves rather as a drainage culvert than as a retaining wall, so that the effective work really consisted in removing all the material down to grade, leaving a slope equal to that of the natural strata.

The total amount finally excavated was about 364,600 cubic meters, while, as already stated, the estimated amount, with slopes of $1\frac{1}{2} : 1$, was 131,652 cubic meters.

It may be in place to add here that in cases belonging to this class of slides, the method of removing the sliding material is usually the best and cheapest, since such slides may take place even without the presence of water, and rain will aggravate the case to such an extent that it is scarcely possible to exercise any control over the sliding masses. Furthermore, a retaining wall, sufficient to hold such masses, would require such dimensions as to prove impracticable at the start.

Another typical example belonging to this class of slides is illustrated in Figs. 4, 5 and 6, *Plate* 1. The cut with the sliding slope is shown in plan in Fig. 4, the strata are given in cross-section in Fig. 5, and the manner of repairing the slide is shown in Fig. 6.

This case is quite similar to the preceding, although not as extensive. It occurred shortly after the cut was excavated, in 1889.

The material of these strata is probably, all considered, the best in the Jurassic period, but owing to the steepness of the strata and the well-defined surface of the micaceous clay under them, the friction on the latter was insufficient to maintain stability after the excavation was made.

The lower portion of the sliding material was removed, as shown in Fig. 6, and the underlying stratum was cut out in order to obtain a footing for the replaced material.

This footing was filled in with stones, as indicated, providing a drain in the lowest portion, and the original material was again filled in. There was no danger in using the sliding material after it had been mixed, as a large portion of it consisted of limestone.

The dotted slope 2 : 1 and the retaining wall show another method proposed, but this would have involved greater expense, with no additional security.

This class of slides, in the nature of the case, embraces cuts only.

Class C.

SLIDES CAUSED BY THE ACTION OF WATER ALONE.

Plate 1, *Fig.* 7. Nordhausen-Wetzlar Railway, Germany. For some time after this embankment had been in use for traffic, no signs of any alarming settlement or slide had appeared. But suddenly, on the 15th of. March, 1881, without any previous warning, the portion shown to the left of the curved line parted from the fill.

The cause was traced to a softening of the material by rain, which reduced the internal friction of the material until the mass became fluid.

The slide extended over a distance of about 25 meters lengthwise of the fill. The softened material was removed and replaced with stony material shown by the shaded area. The sliding surface, or surface of rupture, which was very smooth, was broken up into steps to obviate any future trouble. The remainder, above the stony filling, was replaced by common earth.

Plate 1, *Figs.* 8 *and* 9. Paris, Lyons and Mediterranean Railway. Fig. 9 shows a fill so low that it could scarcely have caused a slide by its own weight, and the sliding surface shown by the dotted curved line indicates that the trouble was the same as that shown in Fig. 7.

Both the slides (Figs. 8 and 9) occurred in consequence of heavy rainfalls which softened the clay. The method of repairing slides of this class is usually some form of that shown here and described in the first case under Class A. The passages cut in the slopes, and afterward filled to the surface with rip-rap, should in these cases be carried down to good, hard material, so as to insure a perfect drainage. The arched branches between the main passages are of little avail. Straight, diagonal passages, about 1 to 1.5 meters in depth, would serve the same purpose of collecting and carrying off rain-water before it penetrates into the material.

The drains provided at the bottom of the main passages serve a very important mission and they should never be omitted. The grade of such drains should never be less than 1 in 10.

When these passages are completed, the earth is again graded to a proper slope and sown with grass.

Plate 1, *Fig.* 10, shows a case where a slide of this class was stopped by means of a retaining wall.

The cut was about 900 meters long, with a maximum depth of 18.5 meters. The material slid on a surface shown by the dotted curve. The wall was built 2 meters above track level, with a breadth of 0.7 meters at crown, and 11 meters at base. Behind it was placed a rip-rap packing, 1.4 meters thick. The wall was subsequently reinforced by buttresses of 1.5 meters width, placed 9 meters apart.

The stone packing is very essential to success, for it secures perfect drainage of the material back of the wall, and thereby avoids the pressure of a semi-fluid mass. The drainage openings through the wall must never be omitted.

Class D.

SLIDES WHERE THE UNDERGROUND IS NOT CAPABLE OF SUPPORTING THE OVERLYING FILL.

This class of slides necessarily embraces embankments only. When earth is filled on any soft alluvium or clay, and especially when the natural surface is inclined, these slides are apt to occur, and they may be of sufficient extent to offer many difficulties.

Slides are aggravated when the substrata are inclined with the natural surface.

Plate 1, *Fig.* 11, represents, in cross-section, a slide on the Bebra-Hanau Railroad, showing its various stages, up to the final stable condition.

As a result of continued rain, in the spring of 1867, the material began to separate at the crown of the fill, and the downhill slope became deformed until a slide ensued.

The cause was erroneously supposed to be a softening of the filling material, and a retaining wall was therefore put in, as shown in Fig. 11, and the embankment was repaired, leaving the berm as indicated by the dotted line.

The work, so repaired, lasted until the fall of the same year, and then, in consequence of heavy rain-fall, the slide reappeared, but on a much larger scale.

This time the underground, to a depth of about 4 meters below the surface, slid, carrying with it about 27,000 cubic meters of the filled material. The culvert was so far disabled that the flow of water through it was nearly stopped.

This waterway was opened up at once and the locality was thoroughly examined. It was found that a second sliding surface, which had not been discovered during the first examination, had formed on the hard slaty clay, and that, in consequence of the weight of the filled material, the softer substrata were dislocated and several springs thus cut off. The water backed up and softened the ground above the slaty clay and the filled earth, to such an extent that the second slide occurred.

Some of the wet material was then removed and these springs opened up again. The ditches *a*, *a*, *a* were next excavated to a depth of 3 to 5.6 meters, penetrating some 0.6 meters into the slaty clay, and were connected, at intervals of about 16 meters, by ditches of the same depth, running at right angles to the axis of the road-bed. These

ditches, filled with rip-rap, served to drain the entire surface. The embankment was then completed by using most of the displaced earth after it had dried out, and no further trouble has since been experienced.

Bolte, the author of the description of this slide, remarks that retaining walls were of little avail in this work, since they usually required extremely deep foundations and very large dimensions in order to resist the pressure of the moving mass. He closes by saying that a reliable method for determining the earth-pressure on the back of a wall still remains to be discovered.

Plate 1, *Fig.* 12, shows a form of slide common in cases where the weight of the filled earth is sufficient to displace the underground at the foot of the slope. The dotted lines in section *a—b* indicate the condition after the displacement.

The alluvium was pushed forward and partly raised by the excessive pressure of the fill, and the material of the slope followed this displacement.

The alluvium to the right of the embankment was then drained by a system of ditches which were filled with rip-rap, and the additional fill to the right was then carried up.

This fill served the purpose of weighting down the alluvium at the foot of the slope and of establishing a new foot under a less pressure. The method is practically equivalent to a flattening of the slope, with such modification in form as to adapt it to the conditions of a case like the one under consideration, where the slide had already taken place.

This is probably the cheapest and best method, and differs only slightly from the case illustrated in Fig. 11.

Plate 2 represents the sliding embankment on the Weizen-Immendingen Railroad, at station 186–187.

This slide, perhaps the most extended of its kind ever met with on railroad work, has not yet been mentioned in any of our American publications.

The embankment, as shown in plan, Fig. 17, was estimated to contain 70,520 cubic meters of material according to the first project, assuming slopes of $1\frac{1}{2}$: 1. The line here passed over a hollow in the hillside, and necessitated cuts to the right and left, separated by the embankment some 320 meters long, between station 184 + 30 and station 187 + 50.

An arched culvert, *o—m*, Fig. 17, was designed and built upon a pile foundation as shown in Fig. 13. The ground or alluvium in this hollow varied in depth from 2 to $9\frac{1}{2}$ meters, and was deepest in the lowest portion, as shown by Fig. 14. The section *p—q*, Figs. 13 and 17, is taken nearly in the bottom, the water-way showing the lowest portion of the hollow.

This alluvium was known to be wet and soft, and very liable to slide when it became loaded down. For this reason no pains were spared to drain the hollow before commencing on the fill.

A system of ditches, varying in depth from 2 to 10 meters, filled with rip-rap and crossing the base of the proposed embankment in all directions, were executed before any filling was done. Considerable water was collected by these ditches, and the ground seemed perfectly drained and ready to carry the load of the filled earth.

Filling was accordingly commenced some time in August, 1888, and continued until snowfall and rain prevented its continuance. In the following spring work was resumed, and, when about two-thirds of the material was in place, a sudden depression at the crown occurred, with a corresponding rising of the material near the foot of the slope, while several cracks in the masonry of the culvert at a, Fig. 13, were observed. This took place in a single night, about the middle of April, 1889.

The area enclosed by the full line for May, in the plan, Fig. 17, and in the corresponding cross-section, Fig. 13, shows the condition of affairs about this time. These lines were determined once a week, and daily measurements were taken to determine the position of the toe, n, of the slide. At the same time weekly determinations were made of the position of the mouth of the old culvert. This point, designated by m in Fig. 17, described the path $m—m'$.

Filling was temporarily suspended until investigations could be made and a new plan of operation decided upon. The mass continued to move slowly, and the lower half of the culvert was broken up into short sections which finally collapsed, so that it was impossible, even with timber work, to maintain an opening. The drainage ditches were by this time disconnected and water began to accumulate on the upper side of the embankment. It now became questionable whether or not the road could be finished and turned over for traffic by May 1, 1890, as intended.

It was impossible to change the location of the line, for the slopes in the cut on the right in Fig. 17 showed indications of sliding, and moving the line would have increased the depth of this cut.

Borings were taken so as to establish contours of the surface of the Opalinus clay, and the canal $s—c—e$, Figs. 16 to 20, was projected. The stulm or tunnel of this canal was immediately commenced from a shaft at s', and the cut at e was simultaneously excavated. A pumping plant was put on the upper side of the bank near s, and the water which had accumulated was pumped over the dam. The shaft at s was then excavated and arched in by a double layer of brick, with an internal diameter of 1.20 m. The pump was removed when this shaft was completed, and the water was again allowed to accumulate.

The filling of the embankment was again taken up with a double force, furnishing about 500 cbm. daily, and the track was thus maintained at grade, but the settlement of the filled earth was so rapid that even with this tremendous force no great increase in width of the dam could be gained until shortly before the completion of the canal work. (See the cross-sections in Fig. 13.)

The clay through which the canal passed was so hard that blasting was necessary, and the work advanced at the rate of only about 1.5 m. per day. The brick masonry (Fig. 18) was put in by another gang as the excavation advanced.

The stulm met the shaft *s*, October 25, 1889, and the water was then drained off. The ditches *h*—*s*—*k* were then dug as shown in profile Fig. 14, and all the water from the hollow was thus cut off. Even before these ditches were completed (December 20, 1889), the motion had ceased and the embankment was filled to somewhat beyond its intended dimensions, in order to allow for settlement and shrinkage during the winter. The ditches were subsequently filled with rip-rap to the natural surface, and the planking at the sides was left in, to prevent the soft material from pressing in between the stones. A considerable quantity of water was collected by this means and carried off through the canal.

The following spring showed no unusual changes or settlements in the dam. The surface of the slide and the slopes were graded and sown with grass, and the road was opened to traffic in accordance with the programme.

During construction a branch stulm, *c*—*d*, Fig. 17, was excavated in order to facilitate an investigation of the condition of the alluvium under the dam, and also to ascertain what had happened to the piles of the old culvert. The ground proved to be comparatively dry, and the piles were found to be inclined down-hill at an angle of about 30° with the horizontal. Most of the piles were probably broken off.

Some of the most interesting observations taken during the time of this work are plotted in Fig. 15. Compare the cross-sections and plans of the slide in Figs. 13 and 17 respectively. The values of *n*, as shown by the dotted line in Fig. 15, represent the motion down-hill of the toe or lowest point of the slide, beginning with *o*, which shows the conditions existing about April 20, 1889. The weekly observations of the mouth of the culvert, designated by *m*, are plotted in the full line on the same figure. In the plan, Fig. 17, the path of the point *m* is shown by the broken line *m*—*m*′.

The curve of *m* shows that the mouth of the culvert moved quite uniformly, and that this uniformity was in a measure the combined effect of the amount of material put into the dam, and of the frictional resistance to the movement of this material. The point *n* moved by

jumps, as might well be expected, since each new movement was followed by a period of rest necessary for storing up new pressure from the fill. An average line drawn through the curve of *n* will, however, resemble the line of *m*, as it should. The line of *m* gives the best indication of the character of the actual motion. It distinctly shows that the material came to rest about December 13, 1889.

It required about 160,000 cbm. of material instead of the 70,520 cbm. estimated, to complete this dam.

Since June 1, 1890, no further difficulty has been experienced with this embankment, a fact which proves not only that the method followed was efficient, but also that the work was faithfully carried out, both of which features are extremely gratifying to the writer, who was in charge of this work.

BALLASTING.

On railroads which have been ballasted for some length of time, the ballast, if supplied as settlement of the track goes on, is invariably pressed into the earth, forming pockets which, extending lengthwise with the road-bed, collect rainwater and often give much trouble. There is always more danger from this cause on fills composed of loosely-filled earth than in cuts.

When water is not drained out of such pockets or depressions, a wash-out or even a severe slide may ensue, but such occurrences may be avoided by cutting 0.5 m. drainage passages at intervals of 10 to 50 m., according to circumstances, and filling these with ballast.

PROTECTION OF SLOPES.

A few remarks on this important subject may be in order here, since slope protection is one of the few preventives of slides, and one which is worth more than almost any amount of cure.

On American railroads it is rarely, if ever, deemed necessary to protect a slope unless some immediate danger is manifest, yet every slope, unless of rock or of stony material, will at least wash, to say nothing about sliding, and this alone is sufficient reason to warrant some protection right at the start.

Of course a road undertaken under conditions of bankruptcy, as many are, cannot afford such constructive details, but any road built with a view to permanency, should protect its slopes at the earliest possible moment.

A slope will wash most when it is new; hence it should be protected by sowing grass on it as soon as graded. It is usually considered best to do this in the fall or spring, but under favorable circumstances the author has attained good results at all times during the summer, sowing

seed as the work progressed. In Europe this is considered one of the essentials of grading, and is highly valued as a protection. It saves more than its first cost, in the maintenance of a road during the second season.

Willow mats have often been employed on wet slopes, but the stakes, which are deeply driven into the ground and between which the weaving is done, open up channels for the water to penetrate the slope, and in a short time a slide occurs. This method, therefore, may do more harm than good, and it is always preferable to use a living growth of willows or locust or of some long-rooted shrubs.

Mat work is very efficient as a shore protection, especially on banks of rivers which deposit sand and silt. Here the mat is loaded with large stones, and the deposit fills up all the spaces, thereby protecting the mat. Or if the mat is undermined, it drops to the newly-formed surface, but continues to act, as before, in catching the deposit.

V. Earth Pressure.

Many volumes have been written and scores of investigators have labored to produce a formula or method for finding the earth pressure on the back of a wall, but it is a lamentable fact that this labor has furnished us with little practical information. The difficulty has always been a lack of experiments on large masses and under the circumstances usually attending earthwork. Our theories are based on small laboratory experiments, usually made with dry sand, and are built up of assumption or imagination. It is, therefore, not surprising that absurd dimensions are obtained by the use of such formulas. It is my aim in the present discussion to state some of the facts at which I have been able to arrive, with a view of leading up to a new method of finding the earth pressure. This may then be regarded as a step in advance of what has been previously done toward getting at the bottom of this matter.

It is vain to expect to arrive at exact results when dealing with such material as earth. The best we can ever hope to do is to approximate to the truth.

It is also useless to experiment with dry earth, for nowhere in nature do we find large masses of earth in a dry state. An embankment constructed from absolutely dry sand would in a short time absorb moisture, and thereby assume entirely different properties.

Of all the experiments, made or to be made, those only are valuable which are made under the actual conditions existing in nature, and of these we will find the extreme cases most valuable. All engineering structures should be so designed as to comply with the most unfavorable conditions which may at any time occur, and this in itself is sufficient reason why experiments and investigations should be made under corresponding circumstances.

A portion of the German Government railroad, Weizen-Immendingen, built in 1887–90, was located in territory pertaining to the Jurassic period. The following conclusions are based upon observations made on this section of the road, the construction of which was under the personal charge of the author.

The material consisted mostly of Opalinus and Turneri clays. About a half million cubic meters were handled in the construction of embankments, varying in height up to 18 meters. The project was based on slopes of 1½ to 1 throughout, and during construction numerous slides occurred, some of which have been mentioned in the preceding examples.

Opalinus and Turneri clays are almost identical in appearance and in composition, and it would be difficult to distinguish between them were it not for the strata which separate them. The Opalinus clay, varying in vertical depth from 45–75 meters, is found in the lower Oolitic and immediately above the upper Liassic epoch. The Turneri clay, with a vertical depth of from 15–21 meters, is located in the middle Liassic immediately above the strata of the lower Liassic. Both clays contain iron, and, when the atmosphere and water have not come in contact with them, they may be of a steel gray or blue color. The usual color, however, is brown or that of ferric oxide, and the presence of a slight percentage of finely divided silica causes them to glisten. In the natural state, whether blue or brown, these clays are very hard, almost slaty, and, on being exposed to the atmosphere and water, they disintegrate into a fine powder which, when wet, presents all possible properties objectionable to the engineer.

Whenever a slide occurred, accurate cross-sections were taken and plotted on the original sections taken for the project. The general method of repairing these slides consisted in cutting vertical passages into the sliding slopes and filling them with rip-rap, as above described. In the course of such repairs the sliding surface, or surface of rupture, became exposed and could be plotted on the corresponding cross sections previously taken, thereby making a complete record of all the conditions attending the slide.

The slides which are here referred to and which prompted the following conclusions, were all caused by depositing material at a steeper slope than it could maintain. They may be regarded as experiments upon a large scale.

Numerous slides occurred also in the cuts through these clays, and, although the slopes of such cuts were quite stable at first, yet it was easy to see that at some future time, when the material disintegrated, it would act percisely as it did in fills. It would follow directly from this fact that the slides which occurred in cuts would not present the same

features as those in filled earth; and in making experiments we must remember that filled earth exerts the maximum pressure, whereas the very same material, in natural strata, may, after cutting, at first exert no pressure at all. This is explained by the fact that the material, in its natural layers, is more compressed or compacted than it will ever be after it has been dug up and moved about.

From these experiments or observations I was enabled to formulate the three following propositions:

1. That what is commonly known as the angle of repose of a certain material, is not a constant angle, but a variable, depending upon the vertical height of the slope.

2. That what is called the plane of rupture, is not a plane but a curved surface whose cross-section closely approaches the form of a hyperbola.

3. That the surface of repose, as would follow from proposition 1, is not a plane, but a curve. For practical purposes, however, we may use an average straight line for the slope.

These three propositions, although they were determined only from experiments on Opalinus and Turneri clays, seem to be true for all materials, except that the relation of the height of slope to the angle of repose, and of the degree of curvature to the surface of rupture, vary for different materials.

It may be that the angle of repose varies less rapidly for sand than for clay, but we have no experiments on large sand embankments to verify this supposition.

It is also possible that, for sandy material, the surface of rupture approaches more nearly to a plane, but all known experiments have been made on so small a scale that the conclusions become erroneous when applied to large masses.

Fig. 21, page 30, represents a cross-section of a slide showing the proposed slope or original condition of the embankment, the actual surface of repose after the slide had established permanent conditions of equilibrium, and the actual surface of rupture corresponding to this surface of repose.

It may require six or eight months for a slope to change from its original to its stable condition, and if the difference between the two is but slight, it may require years. In this case it may take place by gradual settlement and without showing sudden motion.

Let ABC be a given embankment, which, by virtue of the steepness of the slope CB, slides into the position represented by the dotted curved line DEF. The sliding takes place on the *surface of rupture* DF. After complete equilibrium is established between the embankment and the moving mass, the surface line AB is found in the position DE, while the slope line BC takes the irregular curve EF, *the actual surface of repose.*

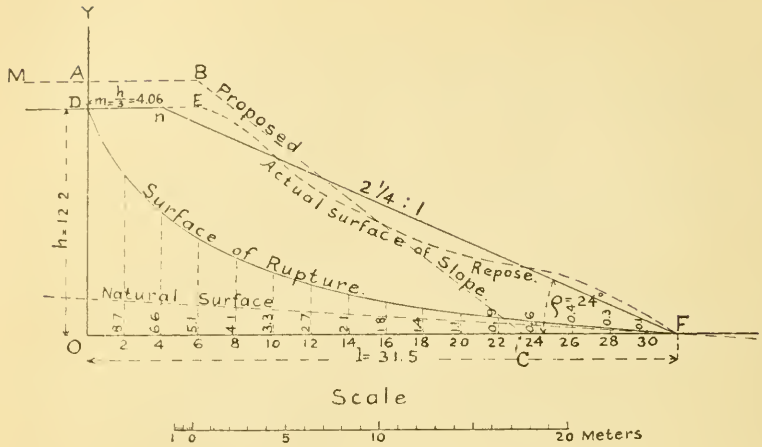

FIG. 21.

The portion ADM, left standing, will have no farther influence on the sliding mass, and we may regard the level of the embankment as changed to DE. We could, of course, fill up the depression from DE to AB, and thus cause the masses to slide farther and to comply with the conditions imposed by the extra loading. The load $ABDE$ would also drop to some position intermediate between AB and DE, and, after a number of repetitions of this process, the conditions of the equilibrium for an embankment of height ODA might be found, but this would give us the same general law that we get by assuming that the portion ADM is removed.

For practical and theoretical reasons, we assume the actual curved surface of slope to be replaced by a plane nF. This will produce little or no difference in the results and will conform with the usual manner of grading. The angle nFO which this plane nF makes with the horizontal FO we call ρ. This angle is found to vary with the height $OD = h$.

It was found, from numerous slides, that in this same material (Opalinus and Turneri clays), the ratio $\frac{Dn}{OD} = \frac{m}{h} = \frac{1}{3}$ nearly. We then find, for clay, the distance

$$OF = l = m + \frac{h}{\tan \rho} = h\left(\frac{1}{3} + \frac{1}{\tan \rho}\right) \qquad (1).$$

Taking the horizontal line OF through the foot of the slope, and the vertical OD through the point D of rupture at the crown of the fill, as axes of co-ordinates, we now determine an equation, with empirical constants, to represent the surface of rupture. These constants will be determined later.

Assuming the curve to be an hyperbola whose axes are parallel to the axes OF and OD, its equation must be of the form:

$$(x + a)(y + b) = c, \qquad (2)$$

where a and b are the co-ordinates of the old origin with respect to OF and OD, and c is a constant depending upon a and b, and upon the eccentricity of the curve.

Taking the co-ordinates of the curve DF from the figure, substituting these in the above equation (2), then solving, from each successive three equations, for a, b and c, and averaging these results, we can get values which may be substituted in equation (2).

It is found, from numerous curves of rupture and for various heights h, that these constants bear the following approximate relations to h and ρ; or, indirectly, to l, since $l = h\left(\frac{1}{3} + \frac{1}{\tan \rho}\right)$.

$$a = \frac{l}{5}, \quad b = \frac{h}{5}, \quad \text{hence } c = \frac{6\,hl}{25} = 6\,ab. \qquad (3)$$

Solving the above equation (2) for y, we have: $y = \dfrac{c - ab - bx}{a + x}$ and substituting from (3), for $c - ab$, its value $5\,ab$, we have:

$$y = \frac{5\,ab - lx}{a + x} \qquad (4)$$

TABLE OF COMPARISON OF OBSERVED AND COMPUTED VALUES OF y FOR DIAGRAM IN FIG. 21, PAGE 31.

Assumed x	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	31.5
Observed y	12.2	9.0	6.7	5.3	4.2	3.2	2.7	2.2	1.8	1.4	1.1	0.9	0.7	0.5	0.3	0.2	0.0
Computed y	12.2	8.7	6.6	5.1	4.1	3.3	2.7	2.1	1.8	1.4	1.1	0.9	0.6	0.4	0.3	0.14	0.0

We are thus enabled to plot the curve of rupture for any case in question, provided we have given h and ρ.

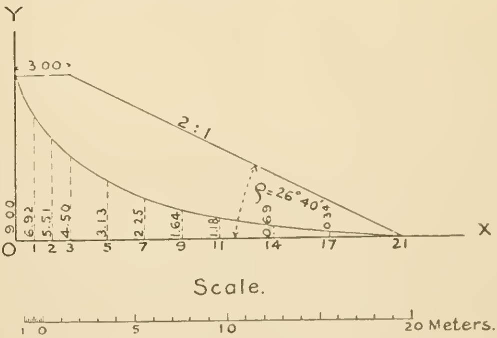

FIG. 22.

TO PLOT THE CURVE OF RUPTURE FOR A CLAY EMBANKMENT OF ANY HEIGHT.

It has been stated above, that the angle of repose was found to be a variable depending upon the height of the fill. From the various em-

bankments which were constructed in Opalinus and Turneri clays, and from the numerous slides which occurred in this material, it has been possible for me to collect the following data, which are probably near enough to the facts for all practical purposes.

TABLE SHOWING RELATION BETWEEN h AND ρ, FOR OPALINUS AND TURNERI CLAYS.

Height of embankment h	0—2m	2—5m	5—10m	10—13m	13—15m	15—20m
Angle of repose ρ	45°00′	33°45′	26°40′	24°00′	22°00′	18°10′
Corresponding slope . .	1 : 1	$1\frac{1}{2}$: 1	2 : 1	$2\frac{1}{4}$: 1	$2\frac{1}{2}$: 1	3 : 1
Tangent of ρ	1.00	0.66	0.50	0.44	0.40	0.33

Hence, for any given h, we can take the corresponding value of *tang* ρ from the above table.

EXAMPLE.

Construct the curve of rupture for a clay embankment whose height above foot of slope = 9 *meters.* It is assumed that a cross-section of the embankment, or rather of the natural surface, is given.

From equation (1), we have: $l = h\left(\frac{1}{3} + \frac{1}{\text{tang}\,\rho}\right)$, and from the above table we get, for $h = 9$, tang $\rho = 0.50$,

$$\text{hence } l = 9\left(\frac{1}{3} + \frac{1}{0.5}\right) = 21\ m.$$

Also, from equations (3), we obtain the values of a, b and c. $a = \frac{l}{5} = \frac{21}{5} = 4.2$, $b = \frac{h}{5} = \frac{9}{5} = 1.8$, and $c = \frac{6\,hl}{25} = 6\,ab$, or $c - ab = 5\,ab = 37.8$.

From equation (4) we find values of y for assumed values of x, and plot these co-ordinates, which give us the curve of rupture.

$$\text{Eq. (4) } y = \frac{5\,ab - bx}{a + x} = \frac{37.8 - 1.8\,x}{4.2 + x}$$

Assumed values of x	0	1	2	3	5	7	9	11	14	17	21
Computed values of y	9.00	6.92	5.51	4.59	3.13	2.25	1.64	1.18	0.69	0.34	0.00

This curve is plotted in Fig. 22, page 31. It represents the line of rupture which would be produced were the slope constructed steeper than 2 : 1 for the height of 9 meters.

In conclusion it might be mentioned that the data above given relating to the surface of rupture for clay, may lead to a new theory of earth pressure. The author has attempted to formulate a method for finding the earth pressure against the back of a retaining wall, but the result is still open to numerous objections, and is, therefore, withheld for the present.

It is hoped that the above pages may receive due appreciation, and perhaps lead to some advances in this important branch of engineering.

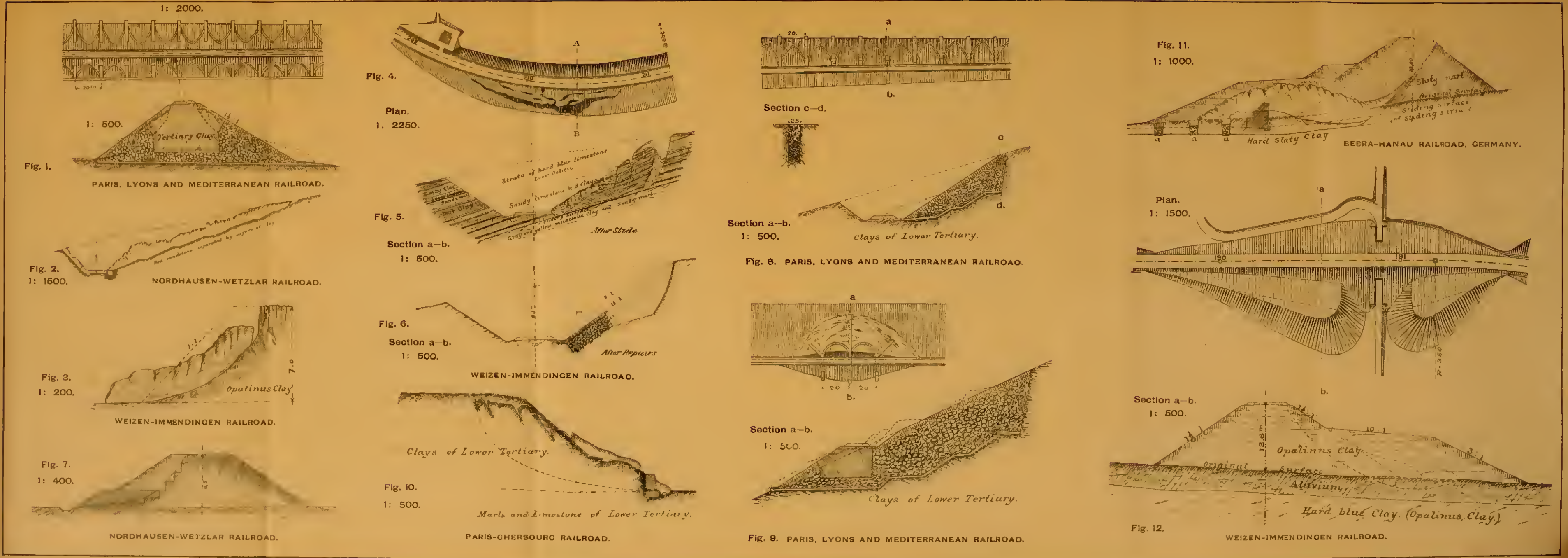
1: 2000.
1: 500.
Tertiary Clay
Fig. 1.
PARIS, LYONS AND MEDITERRANEAN RAILROAD.
Fig. 2.
1: 1500.
NORDHAUSEN-WETZLAR RAILROAD.
Fig. 3.
1: 200.
Opalinus Clay
7.0
WEIZEN-IMMENDINGEN RAILROAD.
Fig. 7.
1: 400.
NORDHAUSEN-WETZLAR RAILROAD.
Fig. 4.
Plan.
1. 2250.
A
B
Fig. 5.
Section a—b.
1: 500.
Strata of hard blue limestone
Sandy limestone
After Slide
Fig. 6.
Section a—b.
1: 500.
After Repairs
WEIZEN-IMMENDINGEN RAILROAD.
Clays of Lower Tertiary.
Fig. 10.
1: 500.
Marls and Limestone of Lower Tertiary.
PARIS-CHERBOURG RAILROAD.
a
b.
Section c—d.
c
d.
Section a—b.
1: 500.
Clays of Lower Tertiary.
Fig. 8. PARIS, LYONS AND MEDITERRANEAN RAILROAD.
a
b.
Section a—b.
1: 500.
Clays of Lower Tertiary.
Fig. 9. PARIS, LYONS AND MEDITERRANEAN RAILROAD.
Fig. 11.
1: 1000.
Slaty marl
Sliding Surface
Hard Slaty Clay
a
a
a
BEBRA-HANAU RAILROAD, GERMANY.
Plan.
1: 1500.
a
190
191
b.
Section a—b.
1: 500.
12.6
Opalinus Clay
Original Surface
Alluvium
Hard blue Clay. (Opalinus Clay)
Fig. 12.
WEIZEN-IMMENDINGEN RAILROAD.

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TABLE SH

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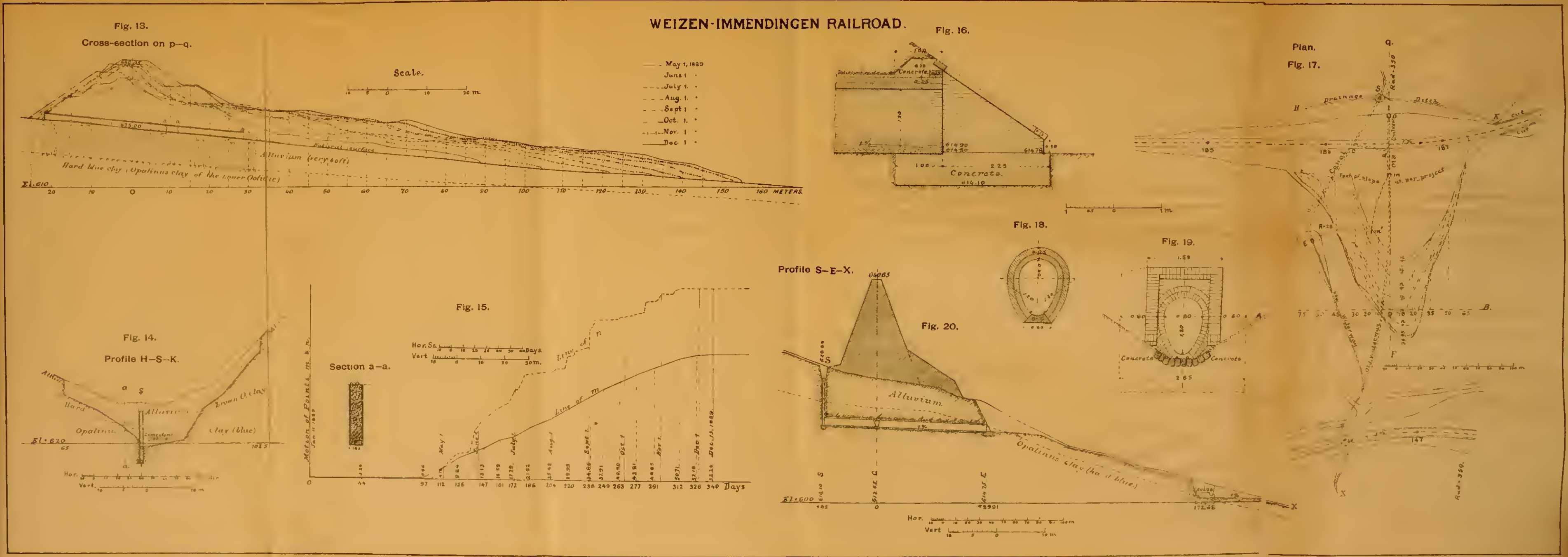
WEIZEN-IMMENDINGEN RAILROAD.
Fig. 13.
Cross-section on p—q.
Scale.
May 1, 1889
June 1
July 1.
Aug. 1.
Sept 1
Oct. 1.
Nov. 1
Dec 1
Natural surface
Alluvium (very soft)
Hard blue clay, Opalinus clay of the Lower Oolite (c)
El. 610
160 METERS.
Fig. 14.
Profile H—S—K.
Alluvium
Brown clay
Clay (blue)
Opalinus
El. 620
Hor.
Vert.
Fig. 15.
Section a—a.
Motion of Points m & n.
Line of n
Line of m
May 1
July 1
Aug. 1
Sept 1
Oct 1
Nov 1
Dec 1
Dec. 13, 1889
Days
Fig. 16.
Concrete
Concrete.
1 m
Fig. 18.
Fig. 19.
Concrete
Concrete
2.65
Profile S—E—X.
Fig. 20.
Alluvium
Opalinus clay (hard blue.)
El. 600
Hor.
Vert.
Plan.
Fig. 17.
Drainage
Ditch
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WATER SUPPLIES.

By Wynkoop Kiersted, Member of the Engineers' Club of Kansas City.

[Read September 11, 1893.]

During the past two years there have been various contentions over water works properties. To a marked degree these contentions have been confined to the Western and Southern States, and to questions concerning water works of comparatively recent construction. They arise not only from strained relations existing between municipal corporations and private water companies, but also from difference of opinion between the officials operating city water works plants.

It is not always easy to determine the causes operating to produce these strifes. They are both real and imaginary, just and unjust, and, aside from political motives, they are frequently traced to the inefficiency of some part of the water works system or to inferiority in the quality of the water supplied. It is not the intent of the writer to discuss directly these several causes and their effects, but to consider briefly the question of water supply itself, more particularly with reference to the Western States, the methods of determining the quality of the water, and practicable methods of preserving its purity as offered to the consumers; for there seem to be good reasons for modifying to some extent the views now held and favored.

Of the 431 water works in the Northwestern and Southwestern States at the close of 1890, 384 have been constructed during the thirteen years since 1880, and of the total number about 50 per cent. are owned by private water companies. This interval of thirteen years, during which the population of these States has increased by more than two millions, included what is frequently referred to as the "boom times," and was marked by a phenomenal increase in the number of water works systems, for nearly every small town is now supplied with water of some kind. During this time few examinations have been made to determine the best source of water supply, the most feasible and convenient one usually being selected, regardless of its quality and potability. The great object seemed to be to "keep up with the times." Doubtless, public sentiment, under the prevailing high tension urging development and progress, permitted many a water works system to be constructed and many of the water supplies to be located on a purely speculative basis.

In many of the towns there is manifested a marked distrust of public water supplies, which, upon investigation, proves to be based

upon an opposition to the paying of water rates, to the unsuitable quality of the water for culinary and industrial purposes, and to suspicions that the supply is impure. A growing appreciation of the convenience of having available at all times and for all purposes a bountiful supply of good water, will remove, in time, the objection to the payment of reasonable water rates; but the other objections are incontrovertible when founded upon fact, and almost equally so when grounded in popular prejudice.

The popular standards of the purity of water are clearness, tastelessness and colorlessness—three characteristics of water which will do more to allay popular suspicion and to prevent criticism than will any other properties, although they are neither definite nor conclusive proof of the purity and potability of a water, but are, in reality, less desirable qualities than are softness, freedom from putrescible organic matter and stability in storage. For instance, a colorless and perfectly clear ground water, especially when high in nitrates, will, if confined in an open reservoir, promote and support a more vigorous growth of organisms and may become fouled and polluted to a much greater extent than will many surface waters similarly confined and either deeply colored by dissolved vegetable matter, or loaded with clay and sand in suspension. Likewise, a water meeting the requirements of the popular standard, but containing much lime and magnesia, particularly in the form of sulphates, is unfit for use in boilers and in houses, while a ground water containing peroxide of iron will cause much trouble and annoyance by the deposits of iron rust in the distribution pipes, and will prove very unsatisfactory in washing and in cooking. In other words, clearness, tastelessness and freedom from color, while, of course, excellent qualities in themselves, afford no criterion as to the purity of a water supply. Nevertheless, they often lead to the selection of inferior sources of supply.

There are many who tenaciously adhere to the use of cistern water for all domestic purposes, in preference to any public water supply, not only because of the superior softness of cistern water, but also because of the still prevailing sentiment that such water is the safest and purest water to drink. This sentiment will, in time, lessen its hold, as our towns become more generally provided with sewerage and house plumbing, and as experience proceeds to demonstrate that the usual receptacles for the storage of rain water and the methods of collecting it do not prevent its pollution.

Likewise it will take time to remove the popular suspicion that waters from sediment-bearing rivers, and those containing the vegetable growths common to surface waters, are necessarily polluted; to establish, to the satisfaction of the majority, that the fitness of a water depends rather upon the quality than upon the quantity of its dissolved organic

matter; and to convince the incredulous that there are practical and efficient methods of converting an organically polluted water into one that is both safe and wholesome.

Because of repeated proofs that some diseases are propagated by means of a drinking water which has become infected with certain disease germs, efforts to preserve the purity of our water supplies have, of late years, received a new stimulus. The wide-spread interest taken in this subject is forcibly shown by the work which is being done by sanitarians and boards of health in various States, notably by the Board of Health of the State of Massachusetts, by whom investigations have been for several years conducted in a most thorough manner and with most satisfactory results. A few of our Western States seem to be alive to the situation, but not as thoroughly as the peculiar conditions surrounding our water supplies should suggest. In the reports of several of our State Boards of Health there can be found recorded analyses of water from wells and from public water supplies which were considered of questionable purity; and, although by these analyses the percentage of mineral matters seem to have been completely determined, there is no evidence that any water has been rejected because of its containing more iron and hardening ingredients than is considered advisable in a water that is to be used as a public supply. Judgment of the character of the organic matter in the waters thus analyzed seems to have been frequently based upon the determination of the amounts of free and albuminoid ammonias, supplemented occasionally by that of the chlorine contents. Those amounts have been compared with some arbitrary standard of purity selected by the chemist, and the water has been rejected or accepted solely as a result of this comparison. In but few instances does it appear that a complete sanitary analysis has been made, and in still fewer instances have comments been made concerning the physical characteristics of the water and of its sources.

Most of the so-called standards of purity are of foreign origin, and, in all probability, were intended by their advocates to apply only in a restricted sense and in certain localities where the natural conditions of the waters had been established by many and thorough investigations. In this country we have committed the error of using these standards indiscriminately, and often ill-advisedly, as a basis of comparison, doubtless because of the want of a sufficiency of original data. By adhering to arbitrary standards of purity, a water containing more organic matter than is considered safe by such standards, may be condemned, although in fact harmless; while one containing a less amount may be accepted, although injurious pollution may be perfectly obvious upon inspection. It does not need a chemical analysis to prove that a water is polluted, if putrescible matter can be seen entering it; nor, on

the other hand, should a water necessarily be condemned because high in organic constituents, if an inspection of its source and environment shows that those constituents are of vegetable matter and stable when dissolved. The degree to which organic matter in water is objectionable depends upon the extent to which it can promote and support life, upon the remoteness in time and distance of its origin and upon the character of the polluting matter.

With respect to this organic matter chemistry claims only that it is able to determine its amount, to detect whether it is stable or changeable, and, by noting its changes, to assist in reaching a conclusion as to its character.

No single determination of the chemical composition of surface or other waters can, in itself, constitute a fair basis of judgment regarding their purity; neither can analyses be properly interpreted unless they are complete, at least from a sanitary standpoint, and unless the physical characteristics and environments of the water and of its source are fully known; nor can similar interpretations of analyses be applied indiscriminately to both surface and ground waters. The following table illustrates this point and indicates the erroneous conclusions that may be drawn by comparing the results of analysis with arbitrary standards of purity.

Table Giving the Impurities in Parts per 100,000.

Free Am.	Alb. Am.	Chlorine.	Nitrates.	Source.	Character of Water.	
					Judgment of the Chemist.	Actual.
.0109	.0227	5.000	. .	Well	*Polluted	*
.0092	.0067	2.00	. .	Spring	*Unpolluted	
.0078	.0114	2.40	.	Well	*Suspicious	*
.015	.012	34.97	. .	Private Well	*Polluted	*
.004	.012	1.81	. .	Hydrant	*Suspicious	*
.006	.024	1.57	. .	Surface	*Polluted	*
.0235	.0264	1.89	.0496	Surface	†Polluted	†Polluted, but used as water supply.
.0006	.026	.23	.0056	Surface	†Unpolluted	†Unpolluted.
.0055	.004	4.2	.185	Deep Well	‡Unpolluted	‡Unpolluted, well 150 feet deep.
.005	.028	2.80	.195	Surface	§Polluted	§Vegetable matter, not serious.
.002	.0227	. .	.0077	Surface	‖Unpolluted	‖Unpolluted.
.0288	.0038	10.3	None	Deep Well	‡Unpolluted	‡Unpolluted, well 600 feet deep.
.0296	.0014	14.2	None	Deep Well	‡Unpolluted	‡Unpolluted, well 720 feet deep.
.001	.015	2.30	40.	. . . . . .	. . . .	. . . .

* Water analyses from report of a State Board of Health. Data insufficient for reliable judgment

† Character determined by complete sanitary analyses extending over a period of two years.

‡ Waters completely protected from pollution by impermeable strata of clay and rock.

§ Pond water. Locality not visited by chemist. Only source of pollution is vegetable matter in pond.

‖ Result of long and complete sanitary analyses.

Rather than accept conclusions upon the potability of a water considered with respect to a chemical analysis (*per se*), it is safer to rely upon a study of its history, for this will tell whether it is or is not polluted and, if polluted, the origin of pollution, and whether the pollution is probably of a dangerous character.

The writer does not wish to be understood as deprecating the use of chemistry in determining the purity of water supplies, for doubtless that science will always play a very important part in this work. He advocates the use of analytical results as inferential and corroborative evidence, in conjunction with a thorough knowledge of the physical characteristics of the water and of its source, and, if needs be, with a biological examination, and urges merely the abandonment of comparative reference to arbitrary standards of purity, which are now conceded to be unreliable and misleading in a general application.

In the contamination of our water supplies, mankind is his own enemy. The decaying vegetable matter washed into rivers and streams from cultivated fields, and the mineral impurities added by the erosion of river banks, affect much less seriously the wholesomeness of water supplies than does that matter which is imparted to them as the direct result of our customs, our industries and our manners of living. Chief among these various sources of contamination is sewage, not only because of the offensive matters dissolved and suspended therein, but more particularly because of the innumerable bacteria which are known to infest sewage, some of which are thought to be intimately related to the causation of certain classes of diseases. It has long been the custom to make water the receptacle for the waste products of life and industry and the vehicle for removing them, and to this custom can be attributed the foundation of the water-carriage system of sewage as it is recognized to-day. Objectionable as is the custom of sewage-disposal into the very waters which we are subsequently constrained to drink, the public adheres to it, largely upon the ground of expediency, as the most practicable and the cheapest method of disposal.

The inertia of the masses, moving in lines of established customs and practices, is too great to be easily diverted to other channels of thought and of practice, especially when additional expense and taxation necessarily accompany such change. For this reason it is difficult to introduce methods of sewage purification which would, at least partially, abate the evils of pollution.

Before such methods can receive the stamp of popular approval, convincing evidence must be given that they are actually necessary as a means of self-defense against those epidemics and diseases which are known to be propagated by polluted waters.

There is but little probability of the early adoption of radical

measures to prevent the pollution of rivers and streams, although restrictive laws of this character may, in some instances, be made and enforced.

But, though it may be difficult or impracticable to properly attack and remove this evil, it may yet in many cases be possible to protect the patrons of public water supplies from its effects. Water from almost any source will, at some period of its career, become contaminated by organic matter, but natural processes of purification will often render such matter innocuous. Were this not the case, it would be difficult to find a trustworthy source of water supply.

The theory of the "self-purification" of running streams has many adherents. It is probably based upon the impression, long held, that the processes of change in the organic constituents of water are due to chemical action alone. But recent investigations have shown that the organic matter in running streams undergoes little change by direct oxidation, and that the diminution of this matter in a specific volume of water is due to sedimentation, to dilution and to absorption by plants, so that time and distance, relative to the point of pollution, are necessary for such purification. Furthermore, air forced into the water does not react chemically upon the organic matter, but mechanically displaces the dissolved gases. Dr. T. M. Drown, of Boston, has recently written quite fully and practically upon these subjects.

The natural process of purification, by which organic matter is broken up and destroyed, as such, is not, therefore, a mere chemical process, but rather a vital process, in which, under proper conditions, bacteria or living organisms are the active factors. A knowledge of this process has been presented to us by the combined efforts of the sciences of chemistry and biology. By its application to the purification of water by sand filtration, a water originally polluted can be reduced to a condition free from disease germs, and therefore safe and wholesome for drinking. The claim frequently made—that disease germs and other organisms cannot be removed by filtration—appears, in the light of recent research, as no longer tenable. In fact, nature refutes these statements. We know that rain-water, the source of all water supplies, cannot reach the ground without absorbing organisms and organic matter from the air and putrefying matter from the surface of the ground, and yet ground water, if unpolluted by direct contact with surface drainage, contains little organic matter and few, if any, organisms. This fact, if it denotes anything, proves that the intermittent filtration which the water has undergone has removed from it both life and organic impurities. Those who deny in a general way the efficacy of soil or sand filtration in the purification of water cannot consistently maintain that any natural source of water supply is safe, and when they do unqualifiedly assert the purity of certain waters, as nearly every one does with

respect to natural springs, they tacitly admit the completely purifying power of filtration. The fact that well-waters in towns are often highly polluted does not detract from the force of the statement concerning filtration; for filtration, like all other natural processes, is one of conditions and regime. Such wells are usually unprotected from surface drainage, or are located so near to cesspools or vaults that sufficient time and distance are not allowed for complete purification, and the conditions are otherwise unfavorable to the greatest vital activities.

In a paper read before the recent Engineering Congress in Chicago, by Mr. W. Kummell, of Altona, Germany, where sand-filtration is used, and where biological examinations of the water are made, both before and after filtration, the author states that: "We can be sure that we are able to deliver a good and safely usable water, even from a river not at all protected against pollution through human dejections." The article further states that cholera germs were among those removed by this filtration.

The experiments and investigations conducted for the past six years by the Massachusetts State Board of Health, with respect to the purification by intermittent sand-filtration, are proof of its efficiency and practical utility in removing organic matter and organisms.

Tabulated below are the results of various analyses, taken from the reports of that Board and from other sources, illustrative of the extent to which purification is practicable.

TABLE GIVING IMPURITIES IN PARTS PER 100,000.

FILTRATION OF SEWAGE.

Free Am.	Alb. Am.	Chlorine.	Nitrates.	Nitrites.	Material.
1.8202	0.5302	5.25	0.0000	0.0000	Average sewage for one year, Lawrence, Mass.
0.0014	0.0080	5.25	1.0404	0.0002	" filtrate, one year, thro' fine sand " "
0.0544	0.0265	5.25	1.581	0.0013	" " " " " coarse " " "
0 0011	0.0156		0.006	0.0001	" Unpolluted surface water, Mass.
0.0001	0 0013		0.0199	0.000	" " ground " "

WATER ANALYSIS.

Free Am.	Alb. Am.	Chlorine.	Nitrates.	Nitrites.	Water.
0.0068	0.0160	0 30	0.014	0 0006	{ Unfiltered city water, polluted by sewage.
0.0006	0.0059	0.22	0.0205	0.0000	{ Filtered " "
0.0230	0.0020	12.10	None	None	Unpolluted artesian water.
0 0022	0.0010	2.60	0.005	None	" " "
0.0006	0.0260	0.23	0.0056	0.0001	Surface water, Mass.
0.0055	0.0040	4.20	0.185	None	Ground " Kansas.
0 002	0.0227		0.0077	0 0001	Impounded water.
0 002	0.0040	17.22			Well in Lawrence, Kan.
0.0104	0.0142	64.57			" " "
0.0054	0.0102				{ Cistern before rain.
0.0102	0.0236				{ Same cistern after rain.

These experiments conclusively prove the ability of intermittent sand-filtration to remove not only the organic constituents of sewage, but also over 98 per cent. of the bacteria which infested the sewage at the time of application; and the process has frequently furnished an effluent, which, in its chemical composition, compares favorably with the water from springs known to be unpolluted. We can see also that nearly all the organic matter and substantially all bacteria, including the specific germ of typhoid fever, can be removed from sewage-polluted river waters at a rate of filtration that renders the method one of practical utility.

The similarity of the nitrogen constituents in the filtered water and in natural ground waters indicates that this process of filtration is identical with natural filtration.

The quality of the effluent is of course determined, in any given case, by the mechanical construction of the filter beds, by the quality and arrangement of the filtering material and by the manner of their manipulation, but the practical efficiency of the method may be taken as established.

The topography of many of the Western and Southern States so affects the physical characteristics of the streams and rivers, that apprehension is already felt with respect to the result of sewage and garbage pollution, but the full effect of this prevailing and increasing practice will not be realized until the smaller towns construct sewerage works. To these States, the question of water purification by natural methods of filtration should be of general and absorbing interest, and it will doubtless receive greater consideration when the results of recent investigations come to be more generally known and appreciated.

Many towns are supplied with hard ground water, and that in but small quantities, although there is frequently at hand in much greater quantities a softer surface water which can be rendered perfectly good and wholesome by filtration.

The writer has found that the soft sandstone of the Dakota geological formation, underlying heavy strata of impervious limestone, will furnish, in some localities, considerable quantities of a soft, pure and wholesome water, and can therefore be utilized in localities where there are no drift formations from which a shallow ground-water supply can be drawn. It is necessary, however, to guard against impregnations of iron, since this material, abounding in these sandstones, is dissolved in the water, and has been found to increase in amount after draught commences, even to the extent of coloring the water or of causing a precipitate of iron rust.

The predisposition to favor unpolluted ground water as the safest and purest source of supply is well founded, especially with reference to

small towns and towns of moderate size, but such water should not be heavily impregnated with hardening ingredients. But ground water can not always be obtained in large quantities at reasonable expense, and consequently rivers and other surface waters will probably remain the chief reliance of large cities and towns. It is quite propable that the dangers which threaten cities using water from this source have been frequently overrated, but the tendency is rather toward a greater degree of pollution, and remedial measures of some kind will, therefore, eventually become necessary. Where dependence is placed upon sedimentation for the clarification of water, it is not at all improbable that such measures will take the direction of supplementary sand-filtration.

Although concern on the part of the public with respect to the purity of water supplies is apparent, it is to be particularly noted that among the Central and Western States there has been, as a rule, no well-determined effort to collect and systematize the physical data which are necessary to assist and to guide in the choice and protection of water supplies. It is quite evident that in this respect there is room for legislative action in providing State Boards of Health, or special Boards of Commissioners, with increased executive powers and with liberal appropriations; but, in taking such action, it is necessary to recognize the specific purpose for which these powers and appropriations should be granted, and the consequent need of including among the members of the Boards those whose attention and work is specially directed to the analytical and constructive departments of sanitary and hydraulic science; for only in this way can the practical features of the questions involved receive due attention and those physical data be collected which will enable fair and trustworthy judgment to be passed upon the various questions presented, and which alone will permit of the establishment of a proper basis for preventive measures in cases where they may be demanded.

Were this done, as it is done in some States, and were it required that every project for water supply or for sewerage should be approved by a Board so constituted, the result would be a more general dissemination of knowledge upon these special topics, and we should have fewer ill-advised schemes, and better designs, better construction and better efficiency of water-works and of sewerage systems than now prevail.

Summing up the foregoing remarks, we find:

1. The custom, still prevailing to a considerable extent, of estimating the potability of a water from the sole standpoint of chemical analyses, is liable to lead to erroneous conclusions and is more fallible than is a knowledge of the history of a water and of the physical characteristics of its surroundings. The generally accepted standard of purity should be abandoned. Chemistry should be considered as infer-

ential and corroborative evidence of quality in connection with the natural and biological history of the water. Ground water and surface water should be treated as different materials, and their analyses should be subjected to different interpretations.

2. The separation of water from its organic impurities is a vital process, and is best accomplished, in the case of public water supplies, by intermittent sand-filtration. By this method of filtration, a polluted water can be clarified and rendered safe and wholesome and practically free from bacteria and disease germs. Where pollution cannot be prevented, such filtration is the safest preventive of those diseases which may be transmitted through drinking-water. Filter beds, properly constructed and manipulated, imitate more correctly and successfully the natural means of water purification than do any other appliances.

3. To properly protect our water supplies, it is necessary that State Boards of Health or other organized bodies be granted greater powers of action and facilities for work.

A NEW PRISMATIC STADIA.

By Robert H. Richards, Member of the Boston Society of Civil Engineers.

[Read October 18, 1893.]

The "stadia" is the name given to instruments which measure the distance between two points by means of a telescope placed on one of them and a rod or target held at the other.

If two lines converge toward a point in the object glass of a telescope, then the spaces S^1 S^2 (Fig. 1) between the two lines at any two points will be proportional to the distances D^1 D^2 from the objective to the two points respectively. Or:

$$S^1 : S^2 = D^1 : D^2.$$

If, therefore, the lines are 1 ft. apart at 100 ft. from the objective, they will be 2 ft. apart at 200 ft., 3 ft. at 300 ft., and so on.

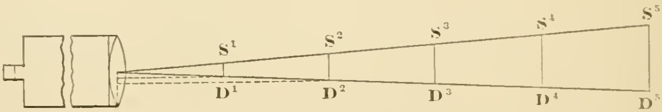


Fig. 1.

In the stadia commonly used the two lines of sight are defined by two spider webs; but, in focusing the instrument, the spider webs move nearer to and farther from the objective as the rod is held farther from or nearer to the telescope, and hence the angle between these two lines of sight varies as indicated in this Fig. 2.

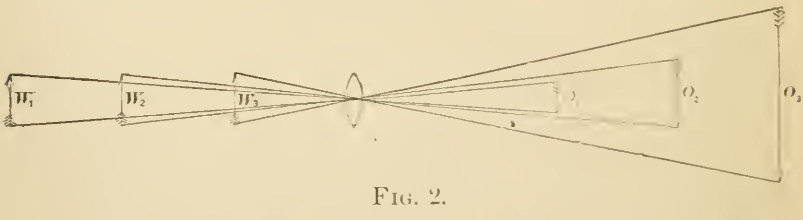


Fig. 2.

If O_1 be the nearer target and O_2 the farther one, then W_1 and W_2 will be the positions of the spider webs respectively, and the angle will differ accordingly in the two cases. There is, however, at a little distance forward from the objective, an imaginary point at which the lines will make a nearly constant angle. To ascertain the position of this point in a Heller transit, I made the following tests:

Taped Distance. T. Feet.	Rod Reading. R. Feet.	T — 100 × R. Feet.	Error from Mean.
10	.087	1.3	—.1
20	.188	1.2	—.2
30	.288	1.2	—.2
50	.487	1.3	—.1
80	.786	1.4	.0
100	.983	1.7	+.3
150	1.487	1.3	—.1
200	1.980	*2.0	+.6
250	2.485	1.5	+.1
300	2.984	1.6	+.2
400	3.984	1.6	+.2
		Average = 1.4	

The imaginary point is therefore 1.4 ft. in advance of the objective.

In the Rochon prismatic stadia there are two quartz crystals so cut and cemented together with reference to their effect upon rays of light that the prism formed by their combination gives two images of every object seen through it. Rochon places the prism between the focal point of the objective and the objective itself, and uses a rack and pinion for moving it back and forth in this space. When the prism approaches the objective, the angle of deviation of the two rays increases to a maximum; when the prism approaches the focal point, the angle diminishes until zero is reached. To make use of this graded angle, Rochon places on the barrel of the telescope a scale, reading to minutes and fractions of minutes, and a scale of cotangents, which, by multiplication with the rod measure, gives the distance required.

In my prismatic stadia I place in front of the objective a prism or wedge of glass which half covers it.

If we hold up such a prism with a narrow angle, say 1° to 2°, and compare the transmitted image with the image seen above or below the prism, the former will be found to be thrown to one side by an amount varying with the angle of the prism. Speaking of the two rays as the direct ray and the bent ray, we may say that when the bisecting plane of the prism is at right angles to the line of sight, the angle between the direct ray and the bent ray will be constant for any given prism.

If now we place a prism in such a position that it half covers the objective of a telescope, we shall obtain, upon looking through it, two images of every object seen—one image by the direct ray, which comes through the uncovered half of the objective, the other by the bent ray which comes through the prism. The angle of divergence of these two rays will be constant and unalterable, whether the telescope is directed to a near or a distant object.

These two rays form the basis of this method of measuring, and the

* This observation was considered inaccurate and was not used in the average.

distance from the telescope to any given point will be proportional to the space between the lines at that point (see Fig. 3). The method of measuring these spaces will be described later under targets.

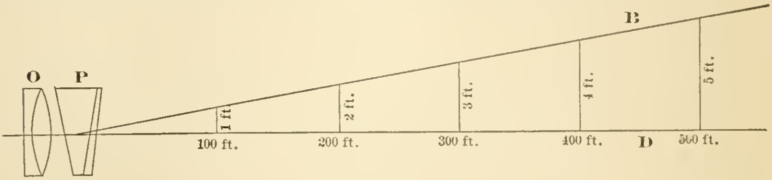


FIG. 3.

In Fig. 3 *O* is the objective of the telescope. *P* is the prism for bending half the light. *B* is the bent ray. *D* is the direct ray. The distances 100 feet, 200 feet, etc., date from a point in the center of the prism.

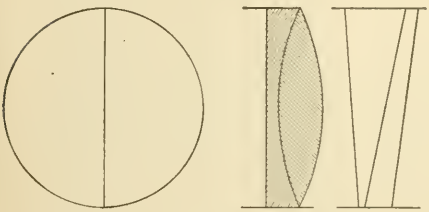


FIG. 4*a*.
Proper Combination.

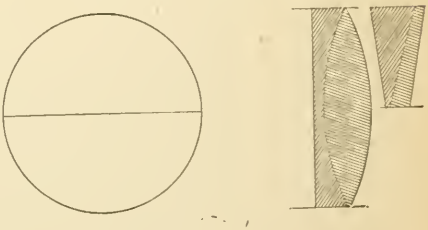


FIG. 4*b*.
Improper Combination.

Fig. 4*a* represents what appears to me to be the rational and proper mode of combining the prism and the objective; while Fig. 4*b* shows an improper combination. With the arrangement shown in Fig. 3 the bent rays will be exact counterparts of the direct rays, while in Fig. 4 this is not the case.

The planes of these prisms must be made as flat as the finest work of the best opticians can render them. A surface with sufficient sphericity to throw the prismatic half of the objective out of the focus with the uncovered half is useless. The prisms made for me by Alvan Clark & Sons give very fine results. The sphericity of these surfaces is a radius of probably not less than seven miles. This sphericity is scarcely visible in front of a telescope of 60 diameters magnifying power.

My early trials were made with a prism such as is used by opticians for eye glasses to correct the direction of sight of the eye. These glasses give a color band instead of a fine line definition, even with a telescope of as low power as 10 diameters; but with higher powers the definition is entirely lost. It is therefore necessary to use, even with such low power telescopes as these, an achromatic combination of flint and crown glasses.

The angle of the prism for general work will be such as to produce a throw of 1 ft. on the rod for 100 ft. in distance (Fig. 3). A prism of 1 ft. to 150 ft. has been tried, but presumably it increases somewhat the percentage of error, and this may, perhaps, offset the advantage gained in the shortening of the target. It should be said, however, in this connection, that test No. 2, which is a test of this prism, is one of the most accurate that was made. A prism giving 1 ft. in 50 is very convenient for a small hand telescope, even more so than 1 ft. in 100; but, although this prism has a less percentage of error than the 1 : 100 prism, yet it requires so long a target for tripod work that its use is not advantageous for distances over 500 feet.

To sum up, I would recommend prisms of the following angles:

For long distances, where extreme accuracy is not required .	1 : 150
For long or short distances, where extreme accuracy is required	1 : 100
For short distances, with a hand telescope	1 : 50

In the prismatic stadia the two spider webs are dispensed with, and in their stead a prism is used in such a way that a double image of the target is formed. The observer, by means of a suitable adjustment, then brings the two images to coincide, whereupon the desired distance is read, either directly or indirectly, upon the rod.

Since the angle, Fig. 3, between the bent ray and the direct ray is constant, the employment of the prism obviates the variation to which the angle is subjected by the use of the spider webs. (Compare Fig. 2.)

The telescope for use with this stadia must be chosen to suit the purpose in view. For a hand telescope, 10 diameters magnifying power is quite powerful enough. On the other hand, if a substantial tripod be used, the higher the power, up to 60 diameters, the better. However, telescopes of 20, 30 or 40 diameters do excellent work. The telescope should give ample light, and upon a tripod a celestial eye-piece can be used quite as handily as a terrestrial one, provided an agreement is made with reference to the targets so as to avoid confusion. The use of telescopes may be thus tabulated:

Power of telescope.	To do strong work.	
60 diameters	for extremely long distance work, up to	6,000 ft.
40 "	for long distance work, up to	4,000 ft.
30 "	" " " "	3,000 ft.
20 "	" " " "	2,000 ft.
10 "	for hand work, up to	300 to 400 ft.

The two images, produced by the direct and bent rays respectively, have a strong analogy to the two images in a sextant. The sea captain brings down the sun's image with one glass till he gets contact between

the sun's disk and the horizon, and the angle is then read from the vernier of the instrument. With the prismatic stadia telescope the lower image is brought into juxtaposition with the upper one, and we read the amount that the lower image has cut off upon the upper one. This reading gives us the displacement of the image, and from this we can compute the distance.

In making an observation we must first focus the two images, next rotate into juxtaposition, and finally read the distance.

The target is made in two forms, the self-reading rod and the tape-target.

The self-reading rod which has been devised for use with this prismatic stadia-telescope, and which gives perfectly satisfactory readings, is shown in Fig. 5. Fig. 6 shows the same rod while being read. The reading in this case is 234 feet. This rod has three stages of graduation; the largest space, namely the space between the large numbers, 0, 1, 2, 3, etc., represents 50 feet, and the single notch of the main scale, 10 feet; while the vernier, which is brought down by the prism into juxtaposition with the main scale, divides that space into units of 2 feet. By the eye further subdivision to single feet can be made. We may say therefore that in the self-reading rod the computations have all been made upon the rod itself, and that instead of reading on the rod the throw or displacement of the image, and then computing the distance, we read at once the computed distance which corresponds to the observed throw.

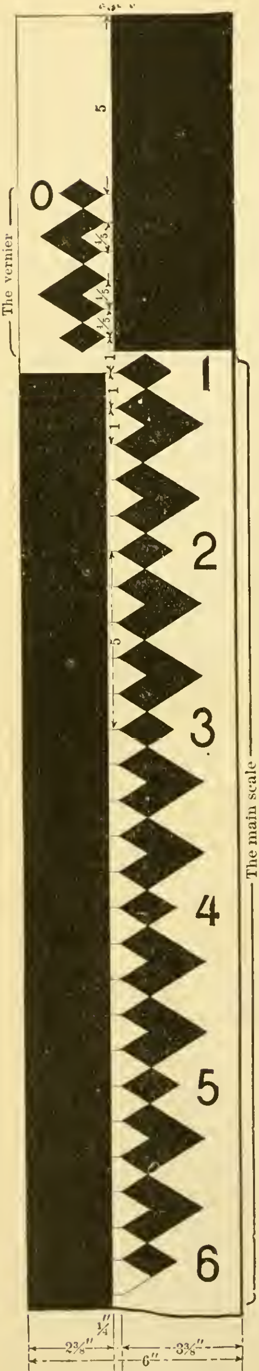
Appropriate combinations of prisms and telescopes may be tabulated thus:

Telescope and Prism.	Distance at which the reading is strong:	Distance at which reading can probably be made:
40 diameters 1 : 100 (on tripod)	1,400 ft.	2,000 ft.
30 diameters 1 : 100 (on tripod)	1,100 ft.	1,600 ft.
20 diameters 1 : 100 (on tripod)	750 ft.	1,100 ft.
10 diameters 1 : 50 (in the hand)	300 ft.	500 ft.

The steps to be taken by the observer are: (1) focus for both rays; (2) rotate to juxtaposition; (3) read the distance. That portion of the target which is being read is the only part that appears clear, distinct and strong.

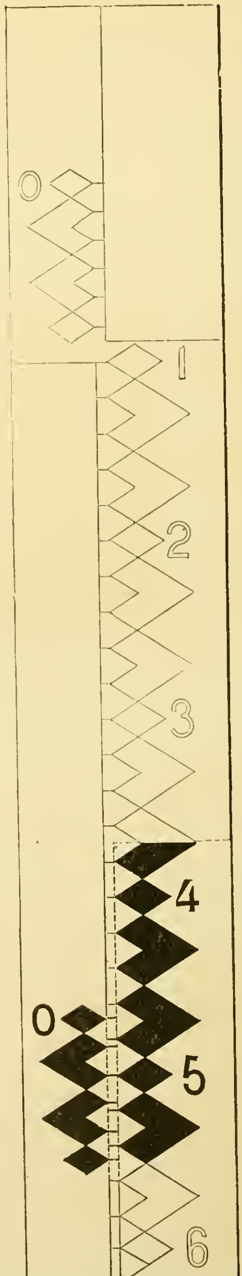
The tape-target is shown in Fig. 7. The tape is held horizontally with two sliding targets, *A* and *B*, upon it. The tape is so attached by a handy clamp to the back of target *A* that its zero exactly coincides

Fig. 5.



SELF-READING TARGET AS SEEN BY THE EYE

Fig. 6.



SELF-READING TARGET AS SEEN THROUGH THE PRISM

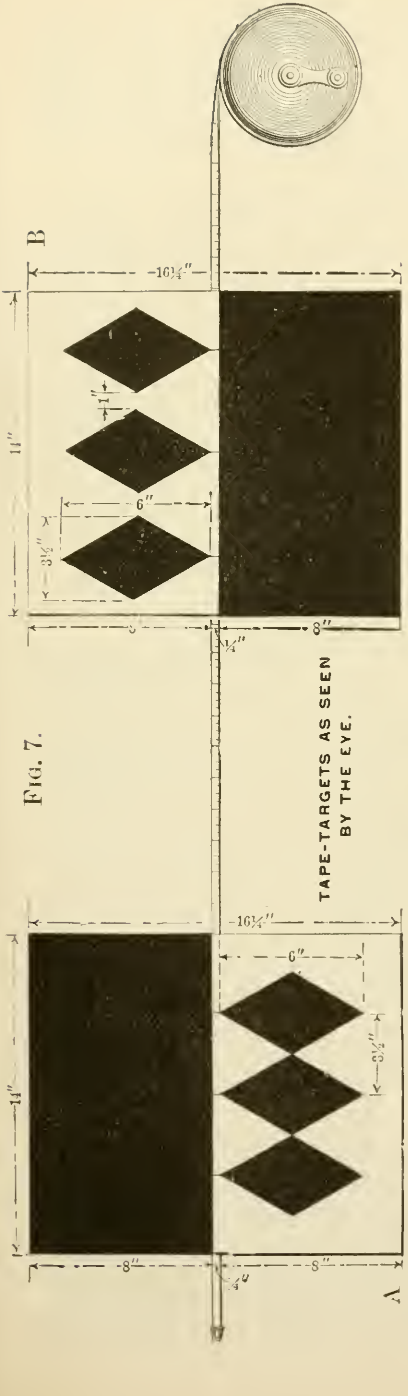

B
16¼″
14″
1″
6″
3½″
8″
¼″
TAPE-TARGETS AS SEEN
BY THE EYE.
16¼″
6″
3½″
14″
8″
8″
¼″
A

Fig. 7.

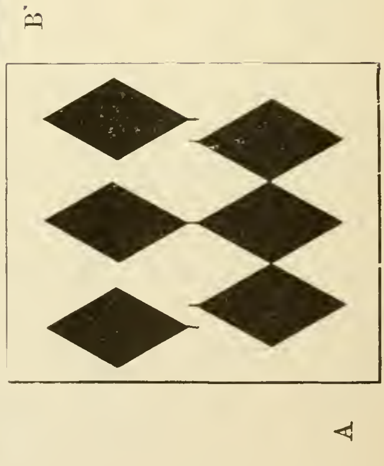

B′
A
TAPE-TARGETS BEING READ BY PRISM.

Fig. 8.

with the point of the center diamond. The target *B* is then moved as the observer directs, being held by a clamp for each observation, until he sees the center diamond of *B* exactly opposite the center diamond of *A*. The reading on the tape is then taken and gives the amount of throw between the direct and bent rays. This throw being obtained, the distance may be computed.

Fig. 8 shows the images as they appear when coincidence is obtained.

The steps taken by the observer are: (1) Focus on both rays; (2) rotate for juxtaposition; (3) signal to the assistant for coincidence. The assistant then reads the tape and records his reading.

This target is more easily read, more accurate and more satisfactory than any other stadia-target known to the writer. The appropriate combinations for targets of sizes indicated above may be tabulated thus:

Telescope and prism mounted on tripod:	Distance at which reading is strong:	Distance at which reading can probably be made:
20 diameters 1 : 100	2,000 ft.	3,500 ft.
30 diameters 1 : 100	3,000 ft.	5,300 ft.
40 diameters 1 : 100	4,000 ft.	7,000 ft.

If the targets were made twice as large as previously indicated in the figures, the distances could be largely increased, though probably not to quite the double of those in the table.

The tape-target must be held at right angles to the line of sight. For this purpose I prefer a Bauernfeind prism or Weldon range-finder. It consists of a right-angled prism, used as is indicated in Fig. 9. Here the line of sight *A* is at right angles to *B*. This prism should have the plane *C* silvered. Otherwise it is a very weak and unsatisfactory tool. The assistant at the tape-target, when standing upon the station, sights with this prism to the observer who is at the other station, and thereby obtains a right-angle range which he can use to line himself up while holding the tape-target for the observation.

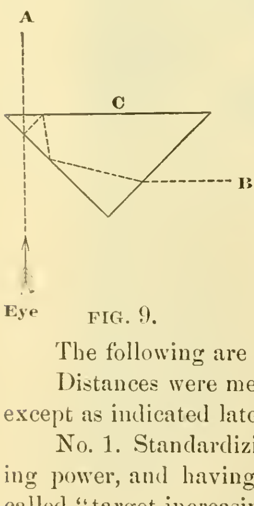


FIG. 9.

The following are the results of a number of different tests:

Distances were measured with a Keuffel & Esser 100-foot steel tape, except as indicated later. The same tape was used for the targets.

No. 1. Standardizing a Bardou telescope of 20 diameters magnifying power, and having a prism of nearly 1 : 100 ratio. The scheme called "target increasing" and "target decreasing" is explained later.

	Distance, 211.38 Feet.			484.94 Feet.	
	Target Increasing.	Target Decreasing.		Target Increasing.	Target Decreasing.
Target readings	1.959	1.958		4.499	4.494
	1.962	1.960		4.497	4.491
Average . . .	1.9605	1.959	Average .	4.498	4.4925
	Final average, 1.95975 ft.			Final average, 4.49525 ft.	

$$\frac{1.95975}{211.38} = \frac{0.927121}{100} = \frac{1}{107.860} \qquad \frac{4.49525}{484.94} = \frac{0.92697}{100} = \frac{1}{107.871}$$

The mean of the two results is

$$\frac{0.927045}{100} = \frac{1}{107.865}, \text{ adopted.}$$

No 2. Standardizing a Bardou telescope magnifying 20 diameters and having a prism of nearly 1 : 150 ratio. In this case a leveling rod with two targets was used.

	1	2	3	4
Distances, ...	127.66	211.35	326.59	484.88
Target readings, ...	.8345	1.3815	2.1325	3.1695
Equivalent for 100 feet, . .	.65368	.65365	.65289	.65366

Average of 1., 2. and 4 = .65366 foot : 100 feet,
or 1 foot : 152.985 feet.

No. 3. Standardizing a Clark 40-diameter telescope having a prism approximating 1 : 100 ratio.

Distances in feet	800	600	400	200
Target readings	7.433	5.566	3.715	1.857
	7.435	5.571	3.715	1.857
	7.428	5.569	3.715	1.855
	7.425	5.563	3.712	1.854
	7.430	5.562	3.714	1.854
Average	7.4302	5.5662	3.7142	1.8554
For 100 feet . .	.928775	.9277	.92855	.9277

Final average, .928131 : 100 feet.
or 1 foot : 107.743

No. 4. Repeating No. 3 with different time, place and measures.

Distances . .	211.38 feet.		484.94 feet.		606.97 feet.		827.42 feet.	
	Decreasing.	Increasing.	Decreasing.	Increasing.	Decreasing.	Increasing.	Decreasing.	Increasing.
								7.680
Target readings	1.963	1.965	4.498	4.498	5.630	5.631	7.677	7.678
	1.962	1.965	4.499	4 500	5.632	5.632	7.676	7.680
Average	1.9625	1.965	4.4985	4.499	5.631	5.6315	7.6765	7.6793
Average by pairs, .	1.96375		4.49875		5 63125		7.6782	
For 100 feet . . .	.929014		.92769		.927763		.927968	

Final average .928109 feet : 100 feet.
or 1 foot : 107.747 feet.

From No. 3 we have 107.743
From No. 4 " " 107.747

Final mean = 107.745, adopted.

No. 5. To measure a long distance, *A B*, with a Clark 40-diameter telescope having a prism with ratio of 1 : 107.745.

< 20 feet >

⊙ *A* ⊙ *B* ⊙ *C*

$$\text{Readings of target} \left\{ \begin{array}{ll} 32.240 & \text{feet} \\ 32.230 & \text{"} \\ 32.235 & \text{"} \\ 32.243 & \text{"} \\ 32.226 & \text{"} \\ 32.235 & \text{"} \end{array} \right. \quad 32.2348 \times 107.745 = 3473.14 \text{ feet.}$$

Average . . . 32.2348 feet.

No. 6. To measure a long distance, *A C*, with a Clark 40-diameter telescope having a prism with ratio of 1 : 107.746.

$$\text{Readings of target} \left\{ \begin{array}{ll} 32.439 & \text{feet} \\ 32.430 & \text{"} \\ 32.450 & \text{"} \\ 32.425 & \text{"} \\ 32.430 & \text{"} \end{array} \right. \quad 32.4348 \times 107.745 = 3494.69 \text{ feet.}$$

Average . . . 32.4348 feet.

No. 7. Summing up Nos. 5 and 6.

A ⊙ *B* ⊙ *C* ⊙

	A C, by Clark telescope,	=	3494.69	feet.
	A B, " " "	=	3473.14	"
Difference,	*B C*, " " "	=	21.55	"
"	*B C*, " tape, "	=	20.00	"
	error.	=	.155	"

No. 8. To measure a long distance, *A C*, by a Bardou 20-diameter telescope having a prism of 1 : 107.865 ratio.

$$\text{Readings of target} \left\{ \begin{array}{ll} 32.350 & \text{feet} \\ 32.349 & \text{"} \\ 32.430 & \text{"} \\ 32.370 & \text{"} \\ 32.370 & \text{"} \\ 32.368 & \text{"} \end{array} \right. \quad 32.3728 \times 107.865 = 3491.89 \text{ feet.}$$

Average . . 32.3728 feet.

No. 9. Summing up Nos. 6 and 8.

By Clark 40-diameter telescope,	$A\ C =$	3494 69 feet.
" Bardou 20-diameter "	$A\ C =$	3491.89 "
Difference		2.80 feet.

No. 10. By the Clark telescope to measure a long distance $D\ E$ and another $D\ F$; the distance $E\ F$ being known to be 16 feet.

⊙ D ⊙ E ⊙ F

Target readings for $D\ E$	13.911 feet.	Target readings for $D\ F$	14.043 feet.
	13.896 "		14.035 "
	13.899 "		14.021 "
	13.900 "		14.037 "
	13.906 "		14.044 "
Average . . .	13.9024 feet.	Average . . .	14.0337 feet.

13.9024 × 107.745 = 1497.91 feet.   14.0337 × 107.745 = 1513.07

	$D\ F$, by Clark telescope	=	1512.06
	$D\ E$, " " "	=	1497.91
Difference,	$E\ F$, " " "	=	14.15 feet.
"	$E\ F$, " tape,	=	16.00 "
	Error	=	1.85 feet.

No. 11. To measure a distance $D\ E$ and another $D\ F$ by a Bardou telescope with a prism having a ratio of 1 : 107.865; the distance $E\ F$ being known to be 16 feet.

Target readings	13.887 feet.	Target readings	14.050 feet.
	13.873 "		14.039 "
	13.890 "		14.042 "
	13.883 "		14.046 "
	13.893 "		14.040 "
Average . . .	13.8852 feet.	Average . . .	14.0434 feet.

13.8852 × 107.865 = 1497.73 feet.   14.0434 × 107.865 = 1514.79 feet.

	$D\ F$, by Bardou telescope	=	1514.79 feet.
	$D\ E$, " " "	=	1497.73 "
Difference,	$E\ F$, " " "	=	17.06 feet.
"	$E\ F$, " tape	=	16. "
	Error		1.06 feet.

	Clark.	Bardou.	Difference.
$D\ F$	1512.07 feet.	1514.79 feet.	+ 2.72 feet.
$D\ E$	1497.92 "	1497.73 "	— 0.19 "

At the point F it was difficult to hold the tape target square with the line of sight, and this fact probably accounts for the poor work done by both telescopes on that point.

No. 12. To test the principle of the zone of error (described later, see p. 56), on a long distance, by the Clark telescope. In this case the distance was across Jamaica Pond and there was a good deal of flickering in the atmosphere.

Target reading. Increasing.	Target reading. Decreasing.
23.513	23.520
23.512	23.510
23.501	23.509
23.500	23.521
23.501	23.510
Average = 23.5054	Average = 23.514

23.5054 × 107.745 = 2532.589 feet. 23.514 × 107.745 = 2533.515 feet.

Mean, 2533.052
Variation ± .463 feet.

No. 13. To make the same test as No. 12 on another distance just at sunset. The flickering of the atmosphere had increased very much.

Target reading. Increasing.	Target reading. Decreasing.
22.500	22.499
22.480	22.500
22.490	22.480
22.490	22.493

22.490 × 107.745 = 2423.185 feet. 22.493 × 107.745 = 2423.508 feet.

Mean, 2423.346
Variation ± .162 feet.

No. 14. To measue an extremely long distance across a lake facing the sun through a decidedly flickering atmosphere. Using Clark telescope.

Target readings.

47.9 feet accepted by observer.
47.85 " refused by observer, who wanted it increased.
47.95 " refused by observer, who wanted it diminished.

47.9 × 107.745 = 5160.98 feet.

The observer reported that 47.95 was twice as far away from coincidence as 47.85. From this I am inclined to the opinion that the extreme variation would be about 3 ft., or ± 1.5 of error at one mile distant.

The tape used for tests Nos. 1, 4, 12 and 13, is marked George M. Eddy, Brooklyn, N. Y., U. S. Standard. This tape is 0.01 inch thick and .265 inch wide, and has bright markings on a dark back-ground. It was purchased of Messrs. Buff & Berger, in September, 1893, and was then of probably recent manufacture. Of this tape I have had a test made, at Washington, by the U. S. Coast and Geodetic Survey, with tension of 11 lbs., temperature 62° Fahr. Estimated probable error = ± 0.005 inch.

Space on the tape in feet.	Correction in inches to obtain the true distance.	Space on the tape in feet.	Correction in inches to obtain the true distance.	Space on the tape in feet.	Correction in inches to obtain the true distance.
0 to 3	— 0.006	0 to 36	— 0.009	0 to 75	— 0.025
0 to 5	— 0.001	0 to 39	— 0.012	0 to 78	— 0.021
0 to 6	— 0.001	0 to 40	— 0.014	0 to 80	— 0.024
0 to 9	— 0.006	0 to 42	— 0.015	0 to 81	— 0.020
0 to 10	— 0.005	0 to 45	— 0.019	0 to 84	— 0.012
0 to 12	— 0.010	0 to 48	— 0.018	0 to 87	— 0.016
0 to 15	— 0.005	0 to 50	— 0.011	0 to 90	— 0.006
0 to 18	— 0.006	0 to 51	— 0.010	0 to 93	— 0.013
0 to 20	— 0.012	0 to 54	— 0.015	0 to 95	— 0.007
0 to 21	— 0.011	0 to 57	— 0.011	0 to 96	— 0.009
0 to 24	— 0.017	0 to 60	— 0.015	0 to 97	— 0.011
0 to 25	— 0.020	0 to 63	— 0.015	0 to 98	— 0.012
0 to 27	— 0.019	0 to 66	— 0.007	0 to 99	— 0.006
0 to 30	— 0.012	0 to 69	— 0.006	0 to 100	+ 0.002
0 to 33	— 0.017	0 to 70	— 0.012		
0 to 35	— 0.009	0 to 72	— 0.012		

It will be seen from this test that the greatest error, —0.025 inches, corresponding to a space of 0 to 75 feet on the tape, would be .002 feet on the tape target, and this would be only 0.2 feet on the ground. This error at 7,500 feet is much closer than the telescope will read. The error of —0.020, corresponding to a space of 0 to 25 feet, is nearly as large. This would be = .0017 on the tape target, and 0.17 feet on the ground, which, at 2,500 feet, is much closer than the target can be read. See tests Nos. 12 and 13. The error of this tape, in its use for a tape-target, appears, therefore, to be practically nothing.

In order to bring these fourteen tests into a form such that comparisons might easily be made, I have prepared the following table. The reader should bear in mind, however, that the errors here given are only from the very worst observations in each test, and that if the means were taken the error due to the prism would not be more than one quarter as great.

No.	Telescope and Prism.	Distance measured.	Extreme reading variation.	Distance corresponding to extreme reading variation.	Extreme variation per cent.	Extreme error per cent.	Zone of error, from a mean of several readings.	
							Space on the rod or tape.	Corresponding length on the ground.
1	Bordou 1:107.865	212 ft.	.004 ft.	.431 ft.	.203	± .101	.0015 ft.	.162 ft.
	"	485	.008	.863	.178	± .089	.0055	.593
2	Bordou 1:152.985	153*	.00079	.121	.079	± .039	. .	. .
3	Clark 1:107.745	800	.010	1.077	.134	± .067	. .	. .
	"	600	.009	.969	.161	± .080	. .	. .
	"	400	.003	.323	.080	± .040	. .	. .
	"	200	.003	.323	.161	± .080	. .	. .
4	Clark 1:107.745	211	.003	.323	.153	± .076	.0022	.269
	"	484	.002	.215	.044	± .022	.0014	.141
	"	607	.002	.215	.035	± 017	.0005	.054
	"	872	.004	.431	.049	± .024	.0028	.302
5	Clark 1:107.745	3473	.017	1.831	.053	± .026	. .	. .
6	Clark 1:107.745	3495	.025	2.694	.077	± .038	. .	. .
8	Bordou 1:107.865	3492	.040	4.315	.124	± .062	. .	. .
10	Clark 1:107.745	1498	.015	1.616	.108	± .054	. .	. .
	"	1513	.023	2.478	.164	± .082	. .	. .
11	Bordou 1:107.865	1498	.020	2.157	.144	± .072	. .	. .
	"	1515	.011	1.185	.078	± .039	. .	. .
12	Clark 1:107.745	2533	.021	2.263	.089	± .044	.0086	.926
13	Clark 1:107.745	2424	.020	2.155	.089	± .042	.003	.323

The above tests show several stages in the development of the method of using the prism. Test No. 2 was based upon the idea that a single observation at each of several distances would give a satisfactory determination of the factor of a prism. Nos. 3, 5, 6, 10 and 11 were based upon the supposition that the mean of several readings will be more accurate than a single one.

Nos. 1, 4, 12 and 13 are based upon the principle that there is a

* In this case the four measures are combined in one, and 153 is therefore a computed distance.

certain space of extreme variation or zone of error which is capable of being observed and recorded. That is to say, if, when the observer has placed the targets and accepted their position, the target is moved so as to increase the reading by .001 ft. at a time until the observer objects, and the last accepted reading is recorded, and again the target is moved so as to decrease the readings by .001 ft. at a time until the observer objects, and the last accepted reading of this set is recorded; then these two recorded readings will bound the zone of error, and the mean of these will be the most accurate reading that can be obtained.

In No. 13 the great amount of flickering caused the decreasing mean and the increasing mean to be almost exactly alike. The zone of error here scarcely appears at all.

I am now of the opinion that the best standard will be obtained on several distances, the longer the better up to 1000 or 1500 feet, and that several readings should be taken on each, using the principle of the zone of error to obtain the most accurate means. My reason for preferring long distances is that the percentage error of the instrument is decidedly less for long than for short distances.

The advantages claimed for this prismatic stadia-telescope as compared with the usual forms read by spider-lines in the telescope are:

1st. The starting-point for the measurement is within the prism, instead of being at an imaginary point some distance in front of the objective.

2d. Only one observation is required for measuring a distance, and there is therefore only one personal equation instead of two.

3d. The portion of the self-reading target which is to be read is the only part that is distinct. It is therefore unnecessary to hunt for the reading. (See Fig. 6.)

4th. The reading is made in two ways, by convergence of the immediate points read and by double divergence of the contiguous points above and below. This is true of both kinds of target. With the spider-webs, convergence only is used.

5th. It would seem that the probable error should be less where two diamond-points are juxtaposed than where a portion of the target is hidden by the thickness of the spider-line.

6th. The prismatic stadia-telescope can be used in the hand for short distances. This is impossible with the spider-web instruments.

7th. Long distances can be satisfactorily measured by the tape and sliding-targets, but not with the spider-web.

8th. The extreme variation of this instrument is from .2 per cent. to .052 per cent. The extreme error will therefore be from ± .1 per cent. down to ± .026 per cent., diminishing as the distance increases, while the error of the spider-web stadia may be as high as .4 per cent., and often is .2 per cent., and does not diminish with distance.

Comparing this prism with the Rochon prism, we may say that the Rochon tempts the observer to use very narrow angles. It also makes an imperfect angular reading. In both these ways it incurs inaccuracy that the prism here described does not.

The fact that in hot sunshine, which causes great flickering in the atmosphere, the mean of vibrations must be read, has not proved a serious disadvantage. By comparing tests Nos. 12 and 13 it will be seen that the final result is not affected.

Another disadvantage, common to all surveying instruments, is the difficulty of sighting when looking towards the sun. The most difficult sight recorded in this paper, viz: No. 14, was made directly towards a bright sun and with a serious flickering in the atmosphere.

The prism, with ratio of 1 : 100 approximately, mounted to fit a transit or level telescope, costs $25.00. The Bauernfeind prism costs $5.00. A pair of tape-targets will answer for any prism. Self-reading rods should be prepared for each prism according to its ratio or factor; but it appears probable that prisms can be made that will vary only between the ratios 1 : 100 2 and 1: 99.8, and thus vary not more than 0.2 from the ratio of 1: 100. Measures will, therefore, be taken for preparing rods with standard graduation of 1: 100, which will be near enough for most purposes. For other cases a factor will correct for the discrepancy, or a special rod can be made.

THE CONTRIBUTION BOX.

Members of the associated societies, and other persons, are invited to send to the Secretary, for this department of the JOURNAL, such matters of general interest as may come to their notice.

The Box.

In religious organizations, although suitable means are usually provided to enable the members to make their stated and considerable offerings for the support of the establishment, yet it is customary, as some of our readers may know, to pass around, at the meetings, a box for the receipt of such further and minor contributions as the members, or the strangers that are within the gates, may feel disposed to make, and it has been thought advisable, in the case of the JOURNAL, to imitate this practice by providing a department in which might appear those little matters, hardly of sufficient dignity or bulk to form the subject of a formal paper, which yet often rival, if they do not surpass, these more venerable documents in interest and utility.

It will be noticed that there is this difference between the two cases: In religious bodies the box is passed around with some frequency, and the contributions are seldom if ever seen again by the contributors, whereas, in our case, the box will until further notice remain constantly open for the receipt of contributions, and the proceeds will be spread before the members in each issue of the JOURNAL.

The collector looks forward to a generous response from the members of the societies and from those of our engineering friends who are not within any of these folds.

Early Measurements of Flow in Channels.

The first contribution to reach the Box is the following, from Mr. Wm. E. Worthen, who reckons among his "boys" such veterans as Alphonse Fteley and who is thus professional grandfather to a host of risen and rising engineers.

NEW YORK, Jan. 10, 1894.

DEAR SIR:

I submit herewith a reminiscence of the elder days, and I trust it may be of interest to your readers.

My first start was in the summer of 1837, when I filled up a month in the summer college vacation, in taking the heights of water in what was called the empty basin of the Boston Mill Dam, for the case of Horace Gray & Co. *vs.* the Water Power Company. The Commissioners were Judge Shaw, Loammi Baldwin, C. E., and James Hayward, C. E. Samuel M. Felton, then in Col. Baldwin's office, was in charge.

The water-power was made by the Mill Dam, which formed a highway, now

the extension of Beacon Street. Another dike extended from near the center of the Mill Dam to Brookline, making two basins, one of which filled at about high tide, and discharged into the empty basin through the water wheels on the Brookline dike.

The gates opening into and out from the basins were large lock gates, working automatically.

Levels were taken, and bottle float gages set up in boxes at different points of the basin. It was the duty of the young fledglings to take levels of the water hourly, night and day. The day watch was fifteen hours and the night watch nine hours, and before the conclusion of the month the day watch came to be considered the most desirable. I took one gage in the empty basin and watched the gates. As soon as they showed a vertical crack of light above the water I took a gage outside in the river to determine the hardly perceptible head necessary to open the gates. Besides the measure of the water in the basins there was a straight current or bucket wheel running between close wooden abutments, with a curved apron at the bottom, so that virtually all the water passed through the wheel, and its capacity and revolutions were noted. The water from the grist mill was measured in a wooden channel, where the surface velocities were taken by means of floats consisting of apples loaded with shingle nails so that they barely floated.

I was more anxious to test the correctness of the old millwright's saw that "a grist mill will do more work at night than in the day," than to know the result of the suit; and was happy to find by the experiments that the teeth were knocked out of that saw, for they showed that we may apply to the grist mill the words of the Psalmist:—"The darkness and the light are both alike to thee." Under the direction of the late Mr. James B. Francis, whose memoir appears in this number of the JOURNAL, I helped put in measuring wheels of the same kind at Lowell, Mass. There were about five of these, coupled, in the Merrimac Canal. They had solid timber piers between them and occupied a width of fifty feet. The diameter of the wheels was about twenty feet. These wheels were used also to determine, from the nail-cushion apple-floats, a formula for average velocity.

Such was the beginning of the experiments which resulted in Francis' methods of measuring water and in "the Lowell Hydraulic Experiments."

In 1838, under George R. Baldwin, C. E., I measured the water used by the Merrimac Print Works in their tail race. Here the Pitot tube was tried, and a small paddle wheel was used for the surface velocity. The friction of the shaft was counterbalanced by a weight suspended from a string wound on the shaft and carried over a pulley. The weight was so adjusted that no piling up of the water was visible on either side of the floats or paddles. I now usually adopt the Lowell methods of measuring flow, with deep floats in good plank channels, and weirs with hook-gauges for determining the height of water.

Yours, WM. E. WORTHEN.

Recent Experiments on Flow in a Cast-Iron Pipe.

Mr. S. Bent Russell, who represents the Engineers' Club of St. Louis upon the Board of Managers of the Association, contributes the following valuable memorandum.

ST. LOUIS, MO., January 15, 1894.

DEAR SIR:

As two of our new settling basins were ready to hold water this winter it was thought prudent to flood the bottoms to prevent damage by frost. For this pur-

pose water was drawn from the old water-works, flowing by gravity *up* through our new conduit, a distance of about seven miles. It then entered a 12-inch pipe which tapped the conduit, and flowed through this pipe for a distance of about 1600 feet to a small well. From the well it was pumped into the new basin by a pulsometer which raised the water about 28 feet.

As it was possible to measure the rate of flow by observing the depth of water in the basins, the opportunity was taken of determining the friction in the 12-inch pipe.

The pipe was new and clean, and was laid on a level grade from end to end. It was 1631 feet long and the current made one right angle turn through a T branch and three other right angle turns of about three feet radius.

The water had a free fall at the discharge end. Three sets of observations were made, as described below. In each set the water rose about 0.15 foot in the basin and about 0.01 foot was allowed for leakage. The latter rate was determined from other observations. The head on the pipe was nearly constant.

Trial I. January 6, 1894. Discharge, 43,200 cubic feet in seven hours, with an average total head on the pipe of 3.36 feet.

Trial 2. January 8, 1894. Discharge, 43,200 cubic feet, in seven hours, with an average head of 3.37 feet.

Trial 3. January 9, 1894. Discharge, 46,700 cubic feet in 8 hours and 35 minutes, with an average head of 3.41 feet.

From these data I computed values of c in the formula:

$$v = c \sqrt{r\, s}$$

where

v = velocity in feet per second.

r = the mean radius = one-fourth the diameter of the pipe in feet.

$S = \frac{h}{l}$ = the friction head in feet divided by length of pipe in feet.

c = coefficent.

Estimating the loss of head due to entrance and to curves, I conclude that the value of c is from 88 to 93.

This is considerably lower than is given by most authorities on hydraulics. As the measurements of volume were not precise, however, the results may be considered as checking very fairly with the formula in common use.

I send you this note in the hope that it may be of use to those compiling hydraulic data. It shows a result that has been obtained in practice with ordinary cast-iron water pipe laid in the usual manner.

The pulsometer used was pumping all that the 12-inch pipe would deliver, about 1,000,000 gallons in twenty-four hours. It was a No. 10 pulsometer, with 8 inch discharge. It took steam from two 40-horse-power locomotive style portable boilers burning Illinois steam coal. A test with a car load of coal showed a duty of about 2,000,000 foot pounds per 100 pounds of coal, a very low efficiency.

Very truly, S. BENT RUSSELL.

The Conflict Between Iron and Sinews.

We learn that the eleven electric power traveling cranes recently put into use by the Yale & Towne Manufacturing Company, in the yards of the Carnegie

Company at Homestead, are displacing so large a number of laborers as to give rise to general comment. The *Iron Age* states that fifty men, formerly occupied on the work now done by these cranes, have left for other localities; and it is stated on other authority that the first crane alone displaced over thirty men.

And when these fifty men reach the "other localities," what may they expect to find there? Possibly eleven other electric power traveling cranes, displacing fifty other men. At first sight it seems difficult to reconcile the well-known zeal of our great manufacturers for the welfare of the American workingman with the pride which those same manufacturers take in the production of machines which turn so and so many men out of employment and set them looking for other localities, like vermin driven from their nests. Yet, in the long run, the gain to the workingmen may be greater than the immediate loss, for, however perfect our "labor-saving" devices may be, they yet require labor for their production. The substitution of the railroad for the stage-coach, enabling a given number of passengers to be handled by a much smaller force of men, has hardly resulted in a contraction of the labor market.

Perils of the Underground.

Those who have traveled upon the "Inner Circle" of the London Underground Railway will appreciate the following, for which the Box is indebted to Col. H. G. Prout, the genial Editor of the *Railroad Gazette*, and formerly Secretary of the Association of Engineering Societies.

It will be borne in mind that trains run continuously in both directions around "the circle," and that the "carriages," like those in Europe generally, consist each of a series of separate compartments, each provided with two doors, one on each side of the carriage. In such a carriage a gentleman and an elderly lady, strangers to each other, found themselves alone, and approaching a station; whereupon the following dialogue took place:—

She:—Might I ask you, sir, to help me out at the next station?

He:—I should be most delighted, madam.

She:—I would not ask the favor, but you see I'm old and stout and lame, so I have to get out backward, and, every time, just as I get my foot upon the platform, the guard comes along and thinks I'm trying to get in, and before I can stop him he shoves me in and slams the door to, and cries out "Right away," *and I've been around the circle three times!*

Engineers Going Abroad.

Colonel Prout, whose contribution, dealing with a feature of the operation of the London underground railway, appears just above, is about to sail for England, where he will make further studies respecting this and other branches of the British railway system.

Mr. Rudolph Hering, the well-known Sanitary Engineer, and Mr. D. McN. Stauffer, Editor of *Engineering News*, will sail for Genoa in the spring.

Mr. Hering has been appointed a delegate to the International Congress of Medicine, which meets in Rome about April 1st.

THE LIBRARY.

It is proposed to notice briefly in this department of the JOURNAL such engineering publications as may find their way to our shelves.

Publishers are requested, in sending works for review, to state the prices of same.

The Constructor. A Handbook of Machine Design, by F. Reuleaux, Professor at the Royal Technical High School at Berlin, etc., etc. Authorized translation, complete and unabridged, from the fourth enlarged German Edition, by Henry Harrison Suplee, B. Sc., Member Am. Soc. Mech. Engrs., etc. Philadelphia: H. H. Suplee, West Chelten Avenue, 1893. 312 pages, 9 x 12 inches. Closely printed, profusely illustrated, and well indexed. Price, $7.50.

Reuleaux's Konstrukteur, to use the words of the translator, "has during the past thirty years acquired the highest reputation over all Europe, and is so well known to German-reading engineers and students in this country that no excuse is needed for its present appearance."

Professor Reuleaux, as those who were privileged to meet him here last summer well remember, is a man of the broadest catholicity, and it is therefore not surprising that in this work he has drawn liberally from American and English as well as from German practice—a feature which greatly enhances the value of the translation to the English-reading engineer.

The scope of the work is well indicated in its title, and embraces not only the practice but also the theory of machine design, the latter including what would make a very respectable treatise upon Graphic Statics and Graphic Arithmetic. In the practical portion, considerable prominence is given to the subject of Ratchet Gearing, a matter to which, as is well known, the author has given special attention.

With appalling industry, the translator has converted all of the innumerable tables and formulas of the original into English measures. We leave it to our readers to discuss the question whether or not the labor bestowed upon this portion of the work might have been enlisted in a better cause.

Hydraulic Cement. NOTES ON THE TESTING AND USE OF—. By Fred. P. Spalding, Assistant Professor of Civil Engineering, Cornell University. Ithaca, N. Y.: Andrus & Church, 1893. 108 pages, 4½ x 7 inches.

A convenient little book, intended as a text-book for a short course of instruction and as a handbook in the laboratory. The first chapter is devoted to the nature and properties, the second to the testing and the third to the use of cement; while the fourth embodies the very admirable feature of an exceedingly well-arranged index to the literature of the subject. Here the English, French and German works referred to are grouped separately, each arranged alphabetically by authors' names. It seems a pity that the list was not made to comprise the recent experiments of Cav. Luigi Luiggi, in connection with the harbor works at Genoa, but this, of course, would have involved the extension of the index into the wide field of a fourth language. The works referred to are numbered consecutively, and a topical index is added, in which the numbers are arranged under the sub-headings to which they severally belong.

No one will expect to find the whole art and mystery of hydraulic cement

exhaustively handled within the narrow limits of this small volume. Hence no one will be disappointed. It would seem, however, that under testing at least, some illustrations would not have been out of place.

Marine Engineering, The Progress of—, from the Time of Watt until the Present Day. With sixty-seven illustrations. By T. Main, M. E. New York: The Trade Publishing Company, No. 56 Vesey Street, 1893. 248 pages, 5 x 7 inches. $3.00.

This little book, as its title implies, deals primarily with the history and development of marine engineering, yet it contrives to convey a good deal of what to the unitiated may be technical information. The sixty-seven illustrations may be taken as accounting for what would otherwise seem like an excessive price for so small a work. They include wood-cuts of the "Clermont" and "Comet," portraits of Watt and of Boulton, and handsome half-tones of many modern river and sea-going vessels and their machinery, together with a goodly sprinkling of cuts intended for purposes of instruction. The book is neatly printed, and is provided with a table of contents and a list of illustrations, but is innocent of an index.

Cylinder Bridge Piers, Notes on—and the Well System of Foundations. By John Newman, Assoc. M. Inst. C. E., etc. London: E. & F. N. Spon. New York: Spon & Chamberlain, 12 Cortlandt Street, 1893. 136 pages, $5\frac{1}{2}$ x $8\frac{1}{2}$ inches. Closely printed. One diagram. Small index.

This work embodies the substance of a series of articles published in the (English) *Engineering Review*, and of a short paper upon the calculations necessary in designing iron cylinder bridge piers, for which the author was in 1871 awarded a Miller prize by the Council of the Institution of Civil Engineers. The author purposely avoids exhaustive discussion of such matters as wind pressure upon piers, and the pressure of earthwork, which are very completely handled in special treatises; and confines himself pretty strictly to the matter in hand, as indicated by the title, matter which, as he says, "is only to be fragmentarily obtained, and after considerable research in the various engineering journals, books and reports of this and other countries, and especially in the engineering press." For the labor of collating this information he is certainly entitled to the thanks of the profession. This is a practical work by one of those rare practical men who can make fairly good use of the tongue in vogue in their native country. But surely a subject like this ought not to be handled without illustrations, unless, indeed, it be intended for the information of those who know it all beforehand.

Natural Asphalt and Mineral Bitumen, Twenty Years' Practical Experience of—. By W. H. Delano, Assoc. Inst. C. E., General Manager of the Compagnie Générale des Asphaltes de France, Limited. London: E. & F. N. Spon. New York: Spon & Chamberlain, 12 Cortlandt Street, 1893. 73 small pages in large type. Plentifully illustrated.

The author is evidently a man of parts; for either he has, in his twenty years of practical experience with the two materials treated of, succeeded in escaping a world of information, or he is a master either of reticence or of the art of condensation. Counting the illustrations as text, we have here something less than four small and very "fat" pages per year of practical experience. Nevertheless, we think the book will be well worth its very low price to anyone desirous of learning the broad fundamental facts which everybody ought to know concerning the matters treated. The typography and illustrations are excellent, and the latter well chosen.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XIII. FEBRUARY, 1894. No. 2.

IRRIGATION FROM THE YELLOWSTONE RIVER.

BY CHARLES TAPPAN, C.E., MEMBER OF THE MONTANA SOCIETY OF CIVIL ENGINEERS.

[Read November 22, 1893.]

NUMEROUS articles of an extremely misleading character, upon the subject of irrigation from the Yellowstone River, have appeared in the newspapers. Most of these articles have taken as their premises that where there is so much water and so much land, all the water will some day be placed upon the land and a country of great agricultural value will result. They take no account of the great engineering difficulties to be overcome, and I have written this paper in order to point out some of these difficulties.

The United States Geological Survey has made gagings of the flow of the Yellowstone with the following results:

At Horr, during the latter part of August, 1888, the flow was 1,553 cubic feet per second; at Springdale it was 2,111 cubic feet per second. These gagings, taken at an exceptionally low stage of water, show such an abundance of water in the Yellowstone that storage reservoirs on the main stream are altogether superfluous; but, notwithstanding this, under advice of the Director of the Geological Survey, a great many sections of land were withdrawn from agricultural entry to be reserved for reservoir sites, and many settlers were thereby put to great inconvenience. These withdrawals were evidently made without close examination of the ground. In one instance the section withdrawn consisted of the isolated hill north of Livingston, a hill which is plainly shown on

the topographical map of the vicinity published by the Geological Survey. Another section withdrawn could be submerged only by making the town of Livingston itself a reservoir. These examples, I think, justify us in attaching very little weight to the reports of the Geological Survey upon irrigation from the Upper Yellowstone.

Above the Yankee Jim Cañon the valley is entirely too narrow to make it worth a moment's consideration as a field for extensive irrigation works. The cañon is so rough that the construction of a ditch or flume would be unprofitable unless there were some very productive mining enterprise to be benefited. For ten miles below the cañon the valley is narrow and the banks high. At the Point of Rocks a very difficult location is met on the west side of the river, and on the east side a hill two or three hundred feet high presents a precipitous face for at least two miles further down.

It is at Fridley's, about half-way between Livingston and the Yellowstone Park, that the first effort at the utilization of the Yellowstone River has been made, and this is also the first place where such work is economically practicable. Here a ditch 14 feet wide by 4 feet deep has been taken out and is now in process of construction. The work is being done almost entirely by ranchmen, and very little outside capital has been invested. At the end of ten or twelve miles the ditch gains the top of the second bank, and is not over one hundred yards distant from the river. In the course of these ten or twelve miles less than two sections of land can be watered. Immediately on gaining the crest of the bench, the ditch follows a course almost at right angles to the river and begins to be useful. It covers only between 6,000 and 7,000 acres, for the bottom lands are cut off by the mountains that close the valley and form the lower or Livingston Cañon, which is about two miles long. To get water through this cañon very expensive piping or fluming would be necessary, and the amount of land covered by the flume and several miles of ditch at its lower end would not exceed by more than two or three hundred acres what can be covered by a ditch taken from the lower end of the cañon.

Returning up the river and examining the east side, we find, just below the abrupt hill mentioned before, a few miles where the soil does not appear to be suitable for farming, as both Six Mile and Emigrant Creeks run through it, but are not used for irrigation. I am not very well acquainted with this immediate vicinity, but I know from the contour of the ditch on the west side of the river that a ditch on the east side would be very close to the bank at a point seven or eight miles from its head, and then would cover land that can now be much more cheaply irrigated by Mill Creek, a large stream whose waters have not been appropriated to the extent of half of its flow. From the mouth

of Mill Creek to the cañon there are a great many mountain streams, but for several years they have been completely appropriated by the present settlers. In a number of places the river bank is over 100 feet high, and consists of coarse cemented gravel, standing at such an angle that no ditching could be done except by excavating all the way to the top, and fluming would be so frequently destroyed by the caving of the banks that no agricultural profits could repay the expense of repairs. It is clearly impracticable to get a ditch out of the right bank of the Yellowstone above the cañon, unless it be to cover a few acres of some low meadow or island.

On the left bank, just below the cañon, a very large ditch, or, more properly, a canal, has been started. The work done upon it reminds one of a prospector and his mining claim—it amounts to about one hundred dollars a year. This canal was started, not for irrigation, but for furnishing water-power to the smelters that were expected in Livingston a few years ago. It could be made of great benefit agriculturally, if completed. In a length of eight miles it would cover some 4,000 acres of land, including a part of the city of Livingston. This would be the extreme practicable length, for the hills come so close to the river that no additional length would serve any useful purpose. However, the expense of right of way through the city will always prevent it from being completed for purely agricultural uses. If it is to be used for water-power, this expense can be more readily afforded. Continuing down the left bank (which here becomes the north) we find, about three miles below Livingston, the high hills close to the river; and, except for the narrow opening at the mouth of Shield's River, they so continue for some six or seven miles. Between this point and Hunter's Hot Springs, a few ranches are irrigated by the river, but they do not require ditches of any magnitude. For several miles above Hunter's, high and abrupt rocky hills rise directly from the river, and it will, undoubtedly, be many years before land will be of sufficient agricultural value to pay interest upon the amount necessary to build flumes around them. The same condition of affairs continues to exist down the left bank to the eastern boundary of Park County.

The right bank through the Livingston Cañon is extremely precipitous, rising directly from the river to a height of several hundred feet. Just below the cañon is a fine mesa, containing soil very suitable for alfalfa, but the height above the river, at the cañon, is not less than two hundred feet, and a ditch, the cost of which would not be repaid by even the most extraordinary increase in land values, would have to be started twenty miles up the river. Opposite Livingston is the first large ditch taken from the right bank. It starts below a point of rocks with a well-located head-gate. The rocks form an eddy, which pre-

vents injury from rapid current and drift logs. This ditch is about 12 feet wide on the bottom, and 3 feet deep. It is only 3 miles long and covers about 2,000 acres. An extension of three miles more would add only some 500 acres under this ditch, as it is paralleled by another which starts about three miles below Livingston, and which, in a length of 3½ miles, covers nearly 2,000 acres. This ditch is remarkable only on account of its low cost of construction, less than $1,200 being the total amount paid for 3½ miles of ditch, 6 feet wide on the bottom and 18 inches deep. Owing to the unevenness of the surface of the flat, and the cutting necessary to get through the first bank, there were about 100 rods of cut, averaging 4 feet deep. One or the other of the ditches last mentioned may at some time be extended down the river. At no point will they be more than two miles distant from the stream, and the land that could be covered is now supplied by Mission Creek. There would be no interesting engineering problems to solve; in fact, nothing for an engineer to do except set the grade stakes and design three or four short flumes across creeks and coulees.

Above Springdale is a small ditch that is worth mentioning on account of the head-works. An open flume about 4 feet wide and a thousand feet or more in length, is built on short posts set along the edge of the river and partly within it, at the foot of a high rocky bank, where the river is very rapid. During the spring freshets the upper part of the flume is sometimes four or five feet under water, and, in order to anchor it, stones have been piled up on boards nailed to the braces. The flume has stood during the last two spring rises, both of which were unusually high. Another successful method of taking a small ditch from the river is by means of a box, of 12 by 12 inches, cross-section, buried in the gravel until its head reaches low water. During high water, the pressure is sufficient to scour out all the sand that may collect during the rest of the year, and there is no difficulty in keeping the box open.

Between Springdale and Big Timber, several surveys have been made with a view to the construction of works for getting the Yellowstone water to the top of the high banks. Thus far all of these surveys have shown that the expense would be greater than the benefit derived. Big Timber and its vicinity are so easily watered by a ditch from the Boulder that the Yellowstone has not been thought of. Below Big Timber is a valley, from one to three miles wide and about twelve miles long, that can be irrigated from the river. Until recently this valley was a part of the Crow Reserve, and it is probably the only place along the Upper Yellowstone, excepting those already mentioned, where a ditch of any size can be profitably taken out. As to the Yellowstone below the eastern boundary of Park County, I cannot say much from my own

observation. Above Billings are several large ditches that irrigate some thousands of acres of fine farming land. From a report made by a special examiner and engineer, Mr. R. J. Perry, to the Land Commissioner of the Northern Pacific Railroad, I copy the following:

"For two good reasons it will be difficult to take water from the Yellowstone River between Custer Station and Glendive:

"*First.*—Because the river has so slight a fall; and

"*Second.*—Because none of the several widenings of the valley are large enough to attract would-be canal builders to invest large sums."

Mr. Perry gives the gradients of the Yellowstone River as follows:

	Miles.	Total Fall. Feet.	Fall Per Mile. Feet.
Cinnabar to Livingston	51	691	13.55
Livingston to Billings	116	1,373	11.84
Billings to Custer Station	53	390	7.55
Custer Station to Miles	94	372	3.96
Miles to Glendive	78	286	3.66

From the foregoing we cannot draw any great encouragement for irrigation schemes from the Yellowstone River.

Hitherto I have confined my remarks to the Yellowstone River itself. I wish to add that there are many very fine mountain streams all through the upper Yellowstone Valley, and from these streams thousands of acres are irrigated. In the future, when the country has increased in wealth and population, the engineer will be called upon to plan reservoirs for the storage of the waters of these creeks. This will really benefit the country more than great canals from the river, because the soil along the small streams and high up on the foot hills is much more fertile than that in the river bottoms.

DISCUSSION.

Mr. G. O. Foss.—It is probably true that most of the land on the south side of the Yellowstone can be more cheaply irrigated from the tributary streams; but I believe there are two large tracts of land that could be successfully irrigated by canals taken from the main river. One of these tracts, situated on the south side of the river near Forsythe, comprises about 30,000 acres, and the other comprises a larger area of bench land on the north or west side between Glendive and the mouth of the river. The latter, however, would be hard to reach, owing to the slight fall of the river below Miles City. These are large tracts, and considerable capital would be required for the construction of suitable canals; but I believe that water could be put into either of them at a reasonable cost per acre. There is another possible canal, which may or may not be practicable; but which, if constructed, would

cover a large area of high mesa lands on the north side of the river near Billings. It would probably require a canal 150 miles in length, at a cost of at least $1,000,000, and I am unable to state the amount of land that might be covered. The construction of such a canal is, however, not likely to be undertaken in the near future, and except for the two tracts which I have mentioned above, Mr. Tappan's conclusion is undoubtedly correct.

WATER POWER—ITS MEASUREMENT AND VALUE,

With Data Respecting Damages Awarded.

By George A. Kimball, Member of the Boston Society of Civil Engineers.

[Read May 17, 1893.]

In 1889, Hon. A. B. Coffin, Hon. Geo. Heywood and the writer were appointed by the Superior Court a commission to award damages to Willard Sibley and others, caused by the taking of land, water power and mills in the city of Waltham and town of Weston, Mass.

The taking was made by the city of Cambridge, acting under the authority of the State Legislature, for the purpose of additional water supply. The quantity of land taken was 39.63 acres, and on this were located the water power, machine shops, tenements and other buildings. The principal power and buildings were on the line of the Fitchburg Railroad, about twelve miles from Boston and two miles from Waltham, and so located that they could be connected with the railroad by a spur track. The stream is known as Stony Brook, and is a tributary of Charles River.

It is the writer's purpose to record in this paper some of the facts presented in evidence before the commission, the damages paid by several cities and towns, and also such other matters as pertain to the subject of the paper.

MEASUREMENT OF WATER POWER.

It was shown in evidence that the Sibleys owned three different falls. The lower dam had a fall of 10 feet. About 3-5 of a mile above the lower dam was situated the mill dam, with a fall of 19 feet, and here were located the mills and other buildings containing the machinery. About 300 feet further up the stream was another dam, about 5 feet in height, and used in the winter only. The total fall on the land taken was about 34 feet.

The mills at the lower dam were burned many years ago. After the fire the stop planks were removed and the pond was drawn down, lowering the water in the tail race at the mill dam above and making the total fall at the mill dam about 24 feet at the time of taking. The upper dam consisted of a few stop planks placed across the stream at the bridge under the railroad. They had been removed every summer, giving them only winter storage, and their use had been entirely discontinued for several years.

The area of the water-shed at the mill dam was twenty-one and a half square miles.

Mr. James B. Francis, the eminent hydraulic engineer, was called to testify in behalf of the mill owner, and furnished the commission with the data given in table No. 1, showing the quantity and commercial value of the water power taken, based on the data furnished him by the mill owner. The explanation of the table, as given by Mr. Francis and taken from the stenographer's report, is substantially as follows:

"There are various ways of estimating the flow of streams. The flow *at any particular moment* can be determined by measuring through weirs, also by measuring the velocity of a given section.

"To get at the *average* flow, which is the chief point, is a very different matter. To take into account the variations of the seasons would require a long series of measurements, which is seldom convenient; or, proceeding upon another method, to ascertain the area of the water-shed supplying the stream, and the amount of the rainfall upon it. In some regions this would not do, but it does very well in this part of the country, and I think it is the usual method.

"For a number of years the city of Boston has gathered valuable information, which is applicable, I think, to this case. The Sudbury River and the Stony Brook water-sheds are not far apart, and are alike in general character of country. I should think it would be fair to apply to this place the information gained from the Sudbury, that is, I think it is better for our purpose than any information I know of. I have made a table or statement in regard to this power, but it is based on data taken from other parties. I have made no observations myself. I take twenty-two square miles as the area of water-shed.

"The rainfall given in column 3 is the average of eleven years, and is taken from the published observations of the city of Boston. Column 4 gives the percentage of this rainfall, averaging about 45 per cent., which runs off in the brooks and streams. The percentage is usually taken by engineers at about 50 per cent., but I should have taken 45 per cent. without reference to these observations. It will be noticed that it varies widely from month to month.

"From the area of twenty-two square miles, the amount of rainfall, and the percentage gathered, I get the average quantity flowing into the brook per day. This is given in column 5. The average flow in the brook for the year is about 2,881,700 cubic feet per twenty-four hours. Now there are in the year three or four months, which I have taken as February, March and April, when there is an excess of water over what can be advantageously used, and when there is consequently a waste. I have taken May as being a month when, as a rule, the entire flow may be utilized. The average wastage during February, March and April is 3,563,030 cubic feet per day.

TABLE No. 1. BY JAMES B. FRANCIS.

Estimate of the Commercial Value of the Water Power furnished by Stony Brook at the Sibley Privileges, of 26 feet and 10 feet respectively, in Waltham and Weston, Mass. Water derived from a Water-shed of 22 square miles. Data obtained from observations made on the Boston Water Works during the eleven years from 1875 to 1885 inclusive, and recorded in Table 8 of the Report by Desmond Fitz Gerald, dated May 30, 1887, on the capacity of the Sudbury River and Lake Cochituate Water Sheds in time of drought. The water was used during twelve hours per day on water wheels giving a useful effect of 75 per cent. of the total power of the water expended.

Month.	Average Number of Working Days in Each Month.	Rainfall. Average for 11 years, 1875 to 1885, inclusive. Inches.	Flow in the Brook. Percentage of Rainfall.	Average Flow in Brook per Day. Cubic Feet.
January	26.57	4.135	38.3	2,611,100
February	24.21	4.280	74.7	5,836,000
March	26.57	4.352	115.2	8,265,880
April	24.71	3.365	106.4	6,099,790
May	26.57	3.092	62.2	3,170,860
June	25.71	3.146	27.2	1,457,860
July	25.57	3.666	8.3	501,670
August	26.57	4.007	10.3	680,460
September . . .	25.71	2.600	9.4	416,380
October	26.57	4.001	12.7	837,760
November . . .	24.71	4.027	31.1	2,133,680
December .	26.43	3 470	44.9	2,568,760
	309.90	44.141	45.06	
	Total	Total.	Average.	

The following estimates are based upon the assumption that 75 per cent. of the gross power is effective. The falls are taken at 1 foot less than their actual height. The power is supposed to be used 12 hours per day, and the night flow stored.

	H. P.
Power utilized during the eight dry months, 207.84 working days.	
On the fall of 26 feet	68.91
" " " " 10 "	24.81
Total	93 72
During the four wet months, 102.06 working days, available flow, 3,170,860 cubic feet per day	212.11
Average for the entire year	132.71

The coal required to give 132.71 (steam) horse-power for 309.90 working days, 12 hours per day, 3 pounds of coal per hour, per horse-power, would be 660.97 gross tons.

Cost of 660.97 tons of coal at $5.00 per ton, delivered at mill and $1.00 per ton for expenses at mill	$ 3,965 82
Capitalized value of the coal, at 6 per cent.	66,097 00
" " " " " 5 "	79,316 40
" " " " " 4 "	97,145 50

The City Engineer of Cambridge, Mr. Lewis M. Hastings, presented to the commission Table No. 2, showing the quantity of power as computed by him.

Table No. 2.—Showing the Horse-Power of Stony Brook.

Prepared by L. M. Hastings, City Engineer, Cambridge.

(*a*) At Sibley's Upper Dam, or Mill Dam.

1.	2.	3.	4.	5.	6.	7.	8.	9.
Month.	Days per month.	Rainfall collected. Inches.	Total flow. Cubic feet.	Total flow per minute. Cubic feet.	Power available. Cubic feet per minute.	Horse-power taking head of upper fall at 18.5 feet, and that of lower fall at 8 feet.		Cubic feet per minute, 12 hours per day.
						Gross.	Net = 75 per cent. of gross.	
Jan. . .	31.00	1.821	90,956,770	2,037.60	1750.	61.22	45.92	
Feb. . .	28.25	3.115	155,590,555	3,824.80	3000.	104.94	78.70	
March .	31.00	4.181	208,836,000	4,678.30	3750.	131.18	98.39	
April .	30.00	3.144	157,039,000	3,635.20	2900.	101.45	76.09	
May . .	31.00	1.888	94,303,348	2,112.50	1800.	62.97	47.23	
June .	30.00	0.861	43,005,920	995.50	995.5	34.82	26.11	
July .	31.00	0.459	22,925,952	513.60	513.6	17.97	13.48	
Aug. .	31.00	0.583	29,120,000	652.30	652.3	22.82	17.11	
Sept. .	30.00	0.527	26,323,000	609.30	609.3	21.31	15.98	
Oct. . .	31.00	0.801	40,009,000	896.30	896.3	31.35	23.51	
Nov. .	30.00	1.372	63,529,000	1,586.30	1586.3	55.49	41.62	
Dec. . .	31.00	1.662	83,015,000	1,859.70	1700.	59.47	44.60	

Total, 20,414. Average horse-power for the year, 44.06.

(*b*) At Sibley's Lower Dam.

Jan. . .	31.00	1.821	90,956,770	2,037.60	1750.	52.83	39.62	3492.4
Feb. . .	28.25	3.115	155,590,555	3,824.80	3000.	71.74	53.81	4742.4
March .	31.00	4.181	208,836,000	4,678.30	3750.	83.09	62.31	5492.4
April .	30.00	3.144	157,039,000	3,635.20	2900.	70.23	52.67	4642.4
May . .	31.00	1.888	94,303,348	2,112.50	1800.	53.59	40.19	3542.4
June .	30.00	0.861	43,005,920	995.50	995.5	30.12	22.59	1991.0
July .	31.00	0.459	22,925 952	513 60	513.6	15.54	11.66	1027.2
Aug. .	31.00	0.583	29,120,000	652.30	652.3	19.74	14.80	1304.6
Sept. .	30.00	0.527	26,323,000	609.30	609.3	18.43	13.83	1218.6
Oct. . .	31.00	0.801	40,009,000	896.30	896.3	27.12	20 34	1792.6
Nov. .	30.00	1.372	63,529,000	1,586.30	1586.3	47.99	36.00	3172.6
Dec. . .	31.00	1.662	83.015,000	1,859.70	1700.	52.07	39.06	3442.4

Total, 20,414. Average horse-power for the year, 33.91.

Column 3 shows the amount of rainfall collectible in this water-shed, based on the average yield of the Lake Cochituate water-shed for 26 years (1863 to 1888), the Sudbury River water-shed for 14 years (1875 to 1888), and the Mystic River water-shed for 11 years (1878 to 1888.)

Columns 4 and 5 show the total flow of the stream, based on an area of 21.5 square miles.

Column 6 shows the amount of water available for power, being the same as No. 5, with an allowance for waste during the months of floods.

Column 7 gives the horse-power of the stream, the heads being estimated as follows:

	Upper dam. Feet.	Lower dam. Feet.
Elevation of crest of dam	90.60	71.14
" " lower basin	71.14	61.00
	19.50	10.14
Allowance for draught on storage at lower dam and getting water on and off wheels, etc.	1.00	2.14

Column 8 gives the usual effect of the power as realized by first-class wheels.

Column 9 shows the amount of water available for power at lower dam, being the natural flow of the stream, plus storage in basins, of about 14.90 acres and 2 feet deep, used in 12 hours a day.

In regard to the wastage represented by the difference between columns 5 and 6, Mr. Hasting says, "I know of no absolute rule which can be applied to all cases. Each case must be considered by itself, with regard to the area and character of the water-shed and the amount of storage available. The usual allowance for waste is from 16 to 25 per cent. of total flow; but wishing to be liberal, I make a smaller deduction.

Messrs. N. Henry Crafts, C. E., and M. M. Tidd, C. E., were called by the City and stated that they had examined the figures made by Mr. Hastings and that they substantially agreed with him in his conclusions.

Mr. Willard E. Sibley, the plaintiff, testified that he had been connected with the mill for many years and had computed the quantity of power at the mill dam as with a fall of 26 feet; and that at the upper dam at the railroad as with a fall of 3½ feet.

He presented to the commissioners his table and work, about which Mr. Francis testified as follows: "I went through the calculations of Mr. Sibley and checked the figurings. I found them all mathematically correct." Mr. Sibley, in computing the power, estimated a storage of night flow at both falls during every month of the year. He had, however, testified in regard to the upper dam at the railroad that "it is our custom to flow the dam from October 1st to May 1st." Mr. Sibley's computation of the power gave 148.42 horse-power as the average for the year.

From the tables of the two engineers, it will be noticed that Mr. Francis gives 132.71 horse-power as the total average for the year, while Mr. Hastings figures it at 77.97 horse-power. The difference in the results obtained by these two engineers is due mainly to their having used different data.

Mr. Francis allows a storage for the night flow at both dams, while Mr. Hastings allows no storage at the mill dam. The fall of the mill dam was taken by Mr. Francis as 26 feet and by Mr. Hastings as 19.5 feet. The fall at the lower dam was taken by Mr. Francis at 10 feet and by Mr. Hastings at 8 feet. Mr. Francis based his figures upon a water-shed of 22 square miles, while Mr. Hastings assumed only 21½ square miles. The data used by Mr. Hastings were determined by actual surveys and were therefore reliable, while those used by Mr. Francis were obtained from the mill owner.

Mr. Francis used the average of collectible rainfall as taken from the Sudbury River for eleven years, while Mr. Hastings averages the Sudbury River for fourteen years, the Cochituate for twenty-six years and the Mystic River for eleven years, but this would make only a slight difference.

The records of the Sudbury River are generally considered the more accurate and reliable data. Mr. F. P. Stearns, Chief Engineer of the State Board of Health, who is familiar with the conditions existing at the Sudbury and with the method of making the measurements, says, page 337 of the 22d Annual Report of the Massachusetts State Board of Health: "Of these the Sudbury River records are the most accurate and the most generally applicable to the conditions existing at other places."

In making allowance for the water wasted in February, March and April, Mr. Francis has taken the flow in May as representing the amount of water that would be available for these three freshet months. Mr. Hastings, in determining the amount of waste water, has not followed any rule, but has used his judgment, based upon his familiarity with the water-shed. Had he followed the same rule as Mr. Francis, he would have been less liberal toward the mill owner. This is shown by his table.

It will be noticed that both engineers have computed the power at each dam separately. The lower dam, as before stated, had not been in use for many years. The stop planks had been removed years before, and this lowered the water in the tail race at the mill dam above and gave it additional head. It was not accessible to the railroad or to the wagon roads, and it is probable that a prudent man would not make use of a power located as this was. The mill dam was quite near a trunk line of railway and on a town road. In the opinion of the writer the

best method of utilizing these powers, is to use the power at the mill dam only, and to increase the fall by removing the lower dam. This was practically the condition of the property at the time of taking. The two powers should have been computed as one, and storage should have been allowed only in the winter months, viz., from October 1st to May 1st.

I have computed the power at the mill dam on this basis and have made use of Mr. Hastings' table No. 2, using all the figures presented by him in columns 1 to 5. In computing the amount of water available for power, I have followed the rule laid down by Mr. Francis for the months of February, March and April, and have substituted for these months the total flow of the month of May. The fall is taken to be 24 feet, as testified by Mr. Hastings. I have allowed one foot for the loss in getting the water on and off the wheel, leaving 23 feet as an average working head. Storage of the night flow is allowed from October 1st to May 1st, and no storage is allowed from May 1st to October 1st. From these data I make the average power for the year 85.77 horse-power.

COMPUTING THE POWER OF A STREAM.

Two methods are usually open to the engineer in determining the amount of power a stream of water will produce:—first, by actual measurements of the flow, and second, by computation of the probable flow as deduced from the area of water-shed and the amount of collectible rainfall. Each of these methods is surrounded with difficulties, and introduces many uncertain elements.

The more accurate method is that by actual measurement, but such measurements, to be of much value, must be continued over a long period of time. The great variation in the flow of all streams renders uncertain the value of data derived from gagings made during a short period of time. In the Sudbury River the average daily flow from 75.2 square miles of water-shed was:

In 1883, 0.824 cubic feet per second per square mile.
In 1887, 1.785 " " "
In 1888, 2.626 " " "

The average for eighteen years, from 1875 to 1892, was 1.663 cubic feet per second per square mile. From these figures we find that the flow in 1883 was less than one-third of that in 1888 and about one-half the average for fifteen years. It is therefore evident that the data derived from the careful gauging of a stream for any single year are not reliable; but systematic records of measurements extending over many years enable us to compute the power of a stream with reasonable accuracy.

The advantage of using the actual flow of a stream to determine

its power is that this method eliminates many uncertain elements, among which may be mentioned the area of the water-shed, the quantity and distribution of the rainfall and the percentage which reaches the stream. The last two of these vary from year to year and from season to season and with the size of the stream. Another advantage of actual gaging is that it shows the extent to which the flow of the stream is affected by storage basins and mills situated on the stream above the power in question.

The other method, or that of determining the power from the area of the water-shed and the records of collectible rainfall, is the one generally used by engineers, for usually these are the best data available. This method has also the advantage that it can be employed within the limit of time and of money fixed for such investigation.

In applying this method, however, the engineer must necessarily use variable elements, and the conditions of the problem with which he is dealing must be carefully compared with those existing at the times and places of obtaining the data he employs.

The determination of the amount of rainfall that may be expected on a given water-shed is not an easy task. There is a wide difference in the rainfall from year to year—for instance, the average rainfall as recorded at Cochituate Lake for the forty years from 1852 to 1891 was 47.98 inches. The maximum, in 1863, was 69.30 inches, and the minimum, in 1883, was 31.20 inches.

There is also a variation as between different places in this State. The rainfall at Lowell during the year 1889 was 41.43 inches, while at Chestnut Hill, about thirty miles away, it was 54.79 inches. This illustration is probably an extreme case, and the variation may be due to local causes. The average rainfall in several places is as follows:

Providence, R. I.,	average for 59 years,	1832–90,	44.51	inches.
Lowell, Mass.,	" 32 "		45.14	"
Boston, Mass.,	" 16 "		47.66	"
Lake Cochituate, Mass.,	" 37 "		47.94	"

The average annual rainfall in Massachusetts, as deduced from long-continued observations in various parts of the State, is 43.17 inches.

The minimum rainfall, as recorded in several places, is as follows:

Providence, R. I.,	minimum from 1832–91	was 30.61	inches,	in 1846.
Lowell, Mass.,	" 1855–91	" 32.418	"	1883.
Boston, Mass.,	" 1871–91	" 35.48	"	1883.
Lake Cochituate, Mass.,	" 1852–91	" 31.20	"	1883.

Records of rainfall are usually accessible to the engineer, but the most important and perplexing question for him to solve is what proportion of the rain falling on the water-shed will reach the stream, and what proportion can be collected and applied for producing power. This

proportion varies from year to year, from season to season and from month to month. Mr. H. F. Mills, C.E., of Lawrence, testified, in the Sudbury River damage cases in 1876, that "it is a common understanding among engineers that, in this part of the world, 50 per cent. of the rainfall of the year, and from 25 to 30 per cent. of that of July, August and September, get into the streams."

Mr. Clemens Herschel, C.E., testified, in the case of Mill Owners *vs.* Town of Arlington, in 1875, that 51.2 per cent. of the annual rainfall reaches the stream, 17¼ per cent. in summer and 73⅓ per cent. in winter. Summer is reckoned from May 1st to September 20th, and winter from September 21st to April 30th.

On the Sudbury River water-shed the records show that 62.21 per cent. of the rainfall was collected in 1888. The average from 1875 to 1890 was 49.10 per cent. On Lake Cochituate 78 per cent. was collected in 1859, and 26 per cent. in 1866, while the average for thirty-eight years was 45.6 per cent. At Mystic Lake 60.34 per cent. was collected in 1891, and 29.84 in 1883, while the average for sixteen years was 46.23 per cent.

It was formerly the rule to deduct from the average rainfall one-half for evaporation, absorption, etc., and 20 per cent. of the remainder for waste, leaving 40 per cent. (with good pondage) available for power.

Table No. 3 was kindly furnished me by Mr. Desmond Fitz Gerald, resident engineer on the Boston Water Works. It shows the yield of the Sudbury River in cubic feet per second per square mile for eighteen years.

TABLE NO. 3. By Desmond Fitz Gerald, C.E.

Yield of the Sudbury River Water-shed in Cubic Feet per Second per Square Mile, for Eighteen Years, from 1875 to 1892, Inclusive.

	1875.	1876.	1877.	1878.	1879.	1880.	1881.	1882.	1883.	1884.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1875–92. Sum.	1875–92. Mean.
January	0.159	0.995	1.019	2.800	1.083	1.733	0,642	1.920	0.518	1.540	1.910	2.260	4.006	1.629	4.305	1.941	4.669	2.893	36.021	2.001
February	2.315	2.116	1.469	3.814	2.647	2.765	2.392	3.718	1.598	4.397	2.095	7.428	4.377	3.011	1.850	2.366	5.393	1.459	. . .	3.064
March	2.482	6.862	7.448	5.426	3.605	2.126	6.195	4.392	2.492	5.857	2.433	3.185	4.437	5.009	2.071	5.636	6.891	3.025	79.573	4.421
April	4.718	5.094	3.703	2.516	4.821	1.808	2.392	1.342	2.088	4.415	2.808	3.013	4.053	4.093	2.182	2.900	3.709	1.348	57.003	3.167
May	1.838	1.761	2.153	2.158	1.723	0.796	1.493	1.998	1.450	1.594	2.067	1.114	1.561	2.526	1.361	2.114	0.901	1.947	30.555	1 698
June	1.346	0.343	0.924	0.782	0.640	0.271	2.070	0.818	0.464	0.644	0.659	0.314	0.640	0 652	1.011	0.878	0.639	0.662	13.757	0.764
July	0.497	0.283	0.312	0.199	0.243	0.273	0.428	0.133	0.178	0.346	0.096	0.179	0.178	0.182	0.980	0.166	0.231	0.331	5.235	0.291
August	0.612	0.627	0.187	0.736	0.611	0.184	0.229	0.086	0.122	0.397	0.372	0.146	0.331	0.587	2.216	0.204	0.252	0.433	8.331	0.463
September	0.321	0.285	0.092	0.249	0.218	0.124	0.305	0.474	0.141	0.068	0.187	0.182	0.172	1.786	1.274	0.708	0 314	0.355	7.255	0.403
October	1.000	0.361	0.977	0.799	0.109	0.157	0.287	0.463	0 288	0.129	0.519	0.225	0.294	3 093	1.903	3.515	0.325	0.195	14.640	0.813
November	2.015	1.683	2.193	2.619	0.318	0.318	0.611	0.324	0.317	0.271	1.822	1.041	0.570	4.267	3.003	1.879	0.457	1.079	24.788	1.377
December	0.903	0.702	1.995	4.916	0.716	0.271	1.199	0.487	0.299	1.431	1.816	1.578	0.995	4.708	3.467	1.541	0.842	0.750	28.616	1.590
Mean	1.504	1.756	1.878	2.246	1,383	0.895	1.515	1.334	0.824	1.747	1.393	1.682	1.785	2.626	2.140	1.989	2.034	1.209	. . .	1.663

Small streams discharge less water per square mile of drainage area than large ones, and the difference is probably greatest in dry seasons. The following figures show the extreme minimum flow of several well-known streams:

Connecticut River, Hartford,	10,234	sq. m.,	0.30	cu. ft.	per second	per sq. m.
Merrimac River, Lawrence,	4,599	"	0.31	"	"	"
Concord River, Lowell,	361	"	0.17	"	"	"
Sudbury River, Framingham,	78	"	0.036	"	"	"
Croton River, W. Branch, N.Y.,	20.37	"	0.016	"	"	"

The Connecticut and Merrimac Rivers are both supplied by large reservoirs, which are drawn upon during the dry season.

Valuable data in regard to the flow of streams and the yield of water-sheds may be found in the following publications:

"Suggestions as to the Selection of Sources of Water Supply," by F. P. Stearns, Engineer of State Board of Health. Published in "Journal of New England Water Works Association," Vol. VI, p. 102; in "Journal of the Association of Engineering Societies," Vol. X, p. 485, and in part in Twenty-second Annual Report of Massachusetts State Board of Health, 1890, p. 333.

"Capacity of the Sudbury River and Cochituate Water-sheds in Time of Drought," by Desmond Fitz Gerald, C.E. A special report to the City Engineer of Boston, dated May 30, 1887.

"Rainfall, Flow of Streams, and Storage," by Desmond Fitz Gerald, C.E. "Transactions of American Society of Civil Engineers," Vol. XXVII, p. 251.

The United States Census Reports, 1880, Vols. XVI and XVII, contain valuable information on water-power and the flow of streams.

VALUE OF WATER POWER.

Mr. Willard E. Sibley, the mill owner, testified that the water power taken was worth $90,000, and the land taken $40,000, making the total damage $130,000.

Mr. Francis, who was called by Mr. Sibley, stated that in order to make this power economically useful and available, it would be necessary to supplement it with steam power in the summer months. Mr. Francis said: "Perhaps I had better make a little explanation at this point. The drift of this whole matter is in my table. According to my experience this power can be best utilized by supplementing the dry time with steam power. I have assumed that three pounds of coal burned per hour are equivalent to a horse-power. In this case we have 132.71 horse-power which is the available amount of water power throughout the year, but this should be supplemented by steam power to make it

uniform. A uniform power, to be most useful, should not be less than 212 horse-power.

"Now I find that, estimating three pounds of coal per hour as equivalent to one horse-power, 132.71 horse-power throughout the year is equivalent to 661 gross tons. I have taken the cost of coal at $5 per ton and the cost of handling at $1 per ton. Water requires no handling after you have got your plant, but coal has to be stored and put into the fire, and the fire must be cared for and the ashes carried away. At $6 per ton for coal, the cost of this 132.71 horse-power is $3,965.82 per year, and this capitalized at 6 per cent., would require $66,097 capital; at 5 per cent., $79,316.40; at 4 per cent., $99,145.50."

Mr. M. M. Tidd, C.E., was called by the City, and testified that in his opinion the Sibley water power alone was not of much value. The tendency of water power is to grow less valuable as the cost of steam grows less. There is an uncertainty about water power. In order to utilize this power at the minimum average horse-power given by Mr. Hastings, it would be necessary to put in steam power. Mr. Hastings gives the average horse-power at the upper dam as 44.06, and in order to keep up this average throughout the year it would be necessary to put in a steam plant. The difficulty is that in manufacturing you are generally in pursuance of a contract or you have to get certain goods into market at a certain time. You have plenty of water at times when you do not need it, but you must have means of getting your goods out whenever they are called for, and there are certain seasons of the year when you have not got the power, and then you are obliged to supplement it by other means. The unsteadiness of water power is what detracts from its value. There may be some years when you would not have any water power.

Mr. Charles T. Main, Mechanical Engineer and Superintendent of the Lower Pacific Mills at Lawrence, Massachusetts, stated that water powers are not in such demand now as formerly, and the first and most important reason for this is the constantly decreasing cost of steam power. Another reason is that in a great many places exhaust steam can be used for various purposes, such as heating, drying, dyeing, etc. Again, a steam-power site can be selected with reference to the markets, to the low cost of fuel, and to the facility of procuring and keeping operatives. With steam power you have a steady power and are not dependent on the rise and fall of the river, and the speed is more uniform with steam than with water power. During the last few years mill sites have been selected near tide-water and have been run by steam power. This is illustrated by the increase in the number of spindles at Fall River, where they have gained about 87,000 per year for the last eight years, while at Lowell the increase has been about 19,000 per year

for the same time, at Lawrence 10,000, and at New Bedford 34,000. The spindles added at Fall River and New Bedford have been run entirely by steam power. Of those added in Lawrence, many are run by steam power, although there is unused water power there.

Mr. Main stated that except for the improvements on the property, the power at the Sibleys' had little or no value.

Mr. Henry W. Britton, a manufacturer, testified that he had examined the power and that in his opinion it was worth $5,000, not including the dam, the buildings or the land.

Mr. Alonzo J. Fiske, an Assessor of Weston for thirty-seven years, considered the water power worth $5,000, exclusive of land and buildings.

The award of the Commission, including all damages for taking land, buildings, water power and machinery, was $34,023 and interest. The city paid in settlement $35,543, with interest and costs. The water power was estimated at $10,000 by the Commissioners.

Reference is made to the following publications:

"Comparative Cost of Steam and Water Power," by Charles H. Manning. Transactions American Society of Mechanical Engineers, 1889. Vol. X, p. 499.

"Cost of Steam and Water Power," by Charles T. Main. Transactions American Society of Mechanical Engineers. 1889. Vol. XI, p. 108.

"The Value of a Water Power," by Charles T. Main. Transactions American Society of Mechanical Engineers. 1891. Vol. XIII, p. 140.

STANDARD FOR FIXING THE VALUE OF WATER POWER.

It will be noticed that Mr. Francis, in fixing the value of this power, has estimated three pounds of coal per hour as equivalent to one horse-power. This would require 661 tons of coal per year; therefore the mill owner would be entitled to receive as damages a sum of money the interest of which would furnish him 661 tons of coal per year.

This method of computing the value of a water power has long been in general use; but although it may be applied in some cases perhaps where only part of the water is diverted from the stream, it seems to me it is not a safe method in all cases. For instance, the cost of coal delivered in some parts of Maine would be excessive, while the water-power, on account of its being remote from transportation, would be of little value.

Again, suppose water power is located in a large city and upon navigable water. In this case the cost of coal would be at a minimum, and the value of the water power, measured by such a stand-

ard, would appear much less than would be considered fair for a power located in so convenient a place. In other words, judged by the standard of pounds of coal, the value of a water-power increases with its remoteness from market. It will readily be seen that a standard of this kind cannot be generally used with safety. The only standard by which we may properly value a water-power is its *market value.*

The market value of a water-power is that price which would be fixed for the property if the owner desired to sell it and another party desired to purchase it. We must not be guided by what the property would bring under a forced sale, or, on the other hand, by the price it would command at a time when the property in the neighborhood was being boomed for any reason, or when the site is wanted for some special purpose. A large manufacturing establishment, desiring to extend its territory, would be willing to pay somewhat more than the market price for land or power which, by its proximity to the existing plant, was peculiarly adapted to its special purposes. In other words, the market value consists in what a person would pay for a piece of property under ordinary circumstances, the purchaser desiring to buy and the owner desiring to sell.

Among the elements which should be considered in determining the value of a water power, the principal one is its location. The same power well located will bring a much higher price than if it were located in some remote place, such as is frequently found in the State of Maine or in the Territory of Nevada, etc., etc. To command the highest price, a power must be accessible to lines of transportation for both the raw and the finished materials. A power located so as to take advantage of both water and railroad transportation, or perhaps of two competing railroads, as is the case at several large industries located near Boston, will bring a much larger price in the market than others located upon a single line of railway. It is also important, in selecting sites for industries of any magnitude, that they be located near the large cities, where labor can be readily procured.

From an engineering point of view we should consider the fall, the quantity of water, its constancy, the facilities for storage, the available locations for dams and reservoirs, the nature of the soil—whether suitable for the erection of permanent dams, for constructing canals, race-ways, etc.,—the probabilities of severe freshets, and the cost of developing the power.

DAMAGES PAID.

In what follows I shall endeavor to sketch briefly several water damage cases, stating the amounts that have been paid by the cities to mill owners where the water has been diverted for municipal uses. The

information has been gathered from many different sources, and I believe it to be as reliable as any that can be obtained under the circumstances.

The most important water damage cases that have been tried in Massachusetts were those against the city of Boston for taking the waters of Sudbury River for an additional water supply in 1872. The Sudbury River is a branch of the Concord River, which flows into the Merrimac River at Lowell. The city of Boston built a dam on the Sudbury in the town of Framingham, and diverted the water for municipal uses from a drainage area of 72.3 square miles. The mill owners below claimed damages for the loss of water, and suits were brought by the following parties: Saxonville Mills, located on the Sudbury River in Framingham; C. P. Talbot *et als.*, and J. R. Faulkner on the Concord River in Billerica; M. P. Wilder *et als.*, owners of the Sterling Mills, L. W. Faulkner and C. B. Snyder, Belvidere Woolen Co., S. N. Wood and Lowell Bleachery, all taking water from a canal leading from the Concord River at the Wamesit dam in the city of Lowell; L. N. Richmond, on the Concord at Massic Falls, in Lowell; the Belvidere Woolen Co., and Middlesex Co., on the Concord in Lowell, near its outlet into the Merrimac, and The Essex Co., on the Merrimac at Lawrence.

The cases were tried in 1876 before a commission consisting of William G. Russell, a lawyer; James B. Francis, C.E., and Chas. A. Stevens, a manufacturer. The testimony and arguments are contained in a volume of about 1200 pages, entitled "Petitions for Damages for Division of Sudbury River by City of Boston." The following information has been obtained from this volume and from the records of the city of Boston.

The Commission made its awards in 1876, and the city appealed. The cases were finally settled for a sum less than the awards, as the following will show:

The Saxonville Mills are located on the Sudbury about three miles below the dam built by the city. It was claimed by the mill owners that all their water was taken by the city. The fall was 26 feet and the drainage area was 73 square miles. The Commissioners awarded $175,000. The city paid $134,611.98.

C. P. Talbot and others, and J. R. Faulkner, own mills located in Billerica, on the Concord River, with 11 feet fall, and a drainage area of 346 square miles, of which 72.3 square miles were taken by the city. The Talbot and Faulkner mills are located at the same dam which was formerly owned by the Middelesex Canal, and by an arrangement made between the two mills the Talbot mill was entitled to a certain quantity of water at all times, while the Faulkner mill was entitled only to the surplus. For a more complete description of the arrangement

between these mills, a reference is made to the "Petitions for Damages," above referred to, page 377. The amount awarded by the Commissioners to C. P. Talbot and others was $76,500, while the amount actually paid by the city was $59,224.81. The amount awarded to J. R. Faulkner was $20,000, and the amount paid was $15,641.69.

The power next below on the Concord River is located in the city of Lowell, and consists of a series of mills located near the lower end of a canal 2,300 feet long and leading from the river at the Wamesit dam. The estimated flow in this canal when the water is even with the top of the dam is 288 cubic feet per second. The fall is 24 feet. The following table gives the quantities to which the several mills are entitled, the amounts awarded by the Commission, and those paid by the city:

				Award.	Amount paid.
L. W. Faulkner & Son	25 cu. ft.	per sec.,		$15,000 00	$11,841 55
C. B. Snyder (Chase Mills)	48	"	"	24,000 00	19,930 28
M. P. Wilder *et als.* (Sterling Mills)	36	"	"	16,500 00	12,986 38
American Bolt Co.	36	"	"		
Belvidere Woolen Co.*	27	"	"	40,000 00	31,510 22
Wamesit Power Co.†	68	"	"		55,000 00
S. N. Wood	12	"	"	7,500 00	6,082 58
Lowell Bleachery.¶	36	"	"	6,000 00	4,910 76
Total	288	"	"		

The property of Nancy L. Richmond is located at Massic Falls, Lowell. The fall is 7 or 8 feet, and the water-shed is about 352 square miles. At the time of taking about 100 horse-power was in use. The award of the Commission was $23,000, and the city paid $17,973.10.

The Middlesex Co. and Belvidere Woolen Co. own mills which are located at the Middlesex dam on the Concord River, near the outlet into the Merrimack. The fall is 10 or 12 feet. The drainage area is about 352 square miles. The Middlesex Company was entitled to a fixed quantity of water at all times, and the Belvidere Co. to the surplus only, of which they owned $\frac{18}{24}$ and leased $\frac{3}{24}$; the case of the Middlesex Company was not before the Commissioners, but the city paid $22,544.95 as damages. The Commissioners' award to the Belvidere Company included two powers; that on the canal leading from the Wamesit dam (referred to above), and that at the Middlesex dam. The award was $40,000, and the city paid $31,150.22.

The Essex Company at Lawrence controls the water power at that place and sells it to other corporations. It has a dam across the Merri-

* Including the company's mills at Middlesex dam, mentioned below.

† The case of the Wamesit Power Co. was not before the Commission.

¶ Lowell Bleachery used water for bleaching, not for power.

mac River with a fall of about 28 feet. The drainage area is 4,599 square miles. Of this area the water-shed taken by the city of Boston on the Sudbury River was 72.3 square miles. The Commission awarded the Essex Company $35,000 damage, but the amount actually paid by the city of Boston was $27,164.59.

In 1873 an Act was passed giving to the town of Arlington, Mass., the right to take water from a brook called Mill Brook, which runs easterly from East Lexington through the town of Arlington, and discharges into Mystic Lower Pond. The town built a dam in the western part of its territory and diverted the water from a drainage area of three square miles. Located at frequent intervals below this dam were several mills that made use of the water for power. These mills brought suit against the town of Arlington for damages, and the case was tried in 1875 before Elias Merwin, James B. Francis and Charles A. Stevens, Commissioners; the first was a lawyer, the second a civil engineer and the third a manufacturer. The following table is taken from the notes of the writer, who testified in the case, and from the records of the Court:

Mill owner.	Fall.	Drainage area		Award.*
		Total.	Taken by town.	
	Feet.	Square miles.	Square miles.	
Carl Schwamb	19.2	3.7	3.0	$13,000
Theodore Schwamb	10.9	3.8	3.0	7,000
J. C. Hobbs	17.5	4.1	3.0	11,100
Welch & Griffiths	18.6	4.4	3.0	18,500
Cyrus Cutter	17.2	4.8	3.0	9,000
Samuel A. Fowle	17.9	4.9	3.0	19,000

The city of Lowell takes water from the Merrimac River above the dam, which is controlled by the Locks and Canals Co., a corporation which owns the dam and sells water to the different manufacturing corporations in the city of Lowell. The case was settled by an agreement dated December 31, 1875, between the city and the company, and the $50,000 paid included not only the damage for taking water, but also for certain pieces of real estate taken by the city for laying pipes, etc.

The city of Lawrence takes water from the Merrimac River above the dam owned by the Essex Company, and the amount paid was $15,000, which included some land. The Legislative Act giving the city of Lawrence the right to take the water contemplated that it would

* The sums awarded bear interest from the time of taking.

be used for domestic supply only, and the city pays the further sum of 5 per cent. on all receipts for water used for running motors, elevators, etc.

The city of Newton and the town of Brookline, respectively, take water from wells or filtering galleries located alongside of Charles River, and above mills located as follows: At Newton Upper Falls, with a total fall of 23 feet at the two dams; next below on the river are the mills at Newton Lower Falls, where there are three dams with a total fall of 23 feet; following down the river we come to the dam of the Boston Manufacturing Co., at Waltham, with water-shed of 184.78 square miles and a fall of 12.10 feet, and at the Bleachery of 4 feet. The Ætna mills, with a fall of 4.80 feet, and the Watertown dam, with a fall of 5.80 feet, when we reach the tide-water in the Charles River.

The city of Newton settled with the mill owners by paying the sum of $25,000 for the privilege of taking 1,500,000 gallons of water daily from the river, and I am informed that a similar settlement was made with the mill owners by the town of Brookline.

The town of Wellesley, which takes water from a filter basin near the same river and between the Upper and Lower Falls, paid the mill owners the sum of $2,131.52 for the privilege of taking 500,000 gallons of water daily, and I understand they are to pay a like sum for each additional 500,000 gallons.

The city of Waltham takes water from a basin near Charles River, just above the dam of the Boston Manufacturing Co. It paid $6,000 and costs of court, etc., for the taking of 1,000,000 gallons daily.

The city of Cambridge takes water from Stony Brook, which enters the Charles near the basin of the Waltham Water Works. It paid the mill owners $15,000, as will be fully explained in the discussion by Mr. L. M. Hastings, City Engineer of Cambridge.*

The city of Cambridge paid $20,000 for damages at Roberts Paper Mill, on Stony Brook near Charles River. The water-shed is 23 square miles and the fall 16 feet. It also paid $35,543, of which $10,000 was estimated as water damages at Sibley Mill; water-shed, 21½ miles; fall, 24 feet, as already mentioned in detail.

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* The data submitted in Mr. Hastings' discussion were published in *Journal of New England Water Works Association*, Vol. VII, page 187.

DISCUSSION.

By Charles T. Main.—At the New York meeting of the American Society of Mechanical Engineers, in 1891, I read a paper on "The Value of a Water Power." I have since seen no reason for changing my views, as then expressed, and before discussing the paper of the evening I should like to read some portions of my own paper as they bear directly upon the subject under consideration.

In estimating the value of a water power it is a common custom to say that the value is represented by a sum of money which, when put at interest, would maintain a steam plant of the same power in the same place.

At first glance this reasoning may appear to be sound, but upon examination it will be seen that it has no foundation, and probably there is no set of conditions under which it would absolutely hold good.

The value of a water power depends upon several factors:

1. The first of these includes the quantity of water, the fall, and the uniformity of flow during the year and for a succession of years.

a. With a low fall, the cost per horse-power of plant will be very much more than that with a high fall, for other things being equal, the first cost of plant and the fixed expenses, such as interest, depreciation, repairs, taxation and insurance, will be greater for the lower head per horse-power; so also will be the running expenses. Hence, less value can be placed on the power itself.

b. It is more difficult to estimate the effect of variable flow upon the value and to determine at what point of variability the power becomes of no value.

If the water-power plant is the only source of power, and if the stream is variable, so that the works must stop for a portion of the time, the power is of very little value except for a very limited range of business. No business, employing any considerable amount of labor, and carried on in such a way, could compete successfully with concerns which have a continuous run.

2. Other things being equal, the value of a water power depends very largely upon its location.

On the erroneous basis indicated at the beginning of my remarks, the farther away from a railroad the power is located, and the more it costs to haul coal to it, the more valuable the power would be; whereas it is a self-evident fact that the nearer the mill can be located to the railroad or seaport, the more valuable the power which drives it.

3. The value depends largely upon the question whether or not the social conditions are, or can be made, such as to cause good operatives to locate and remain in the place; upon the sanitary conditions; and sometimes even, in the case of a developed power, upon the management of a municipal or town government. All of these factors cannot be estimated in dollars and cents, but they, nevertheless, determine to a certain extent the profits or losses.

4. In almost every business there is need for steam for other pur-

poses than power, if only for warming the buildings in cold weather. For these purposes exhaust steam can generally be used, so that little or no more fuel is consumed than is required to produce steam for the engine alone.

The plant required for producing the steam is a necessity when water is used for power, and its cost should be included in that of power-plant, and the expense of running in the cost of producing power.

In estimating the value of a water power it is necessary to consider the power first as undeveloped, and then in its developed state.

The essential points which must be considered are as follows:

a. Quantity of water during a dry year.

b. Uniformity of flow during the year, considering the natural and artificial storage capacity.

c. Head of fall.

d. Conditions which fix the expense of building dam and canal, and flowage of land.

e. Conditions which affect the cost of fonditions for buildings.

f. Geological conditions which determine the permanency of the fall.

g. Freight charges for fuel, supplies, raw materials, and finished product.

h. How much low pressure steam can be used for heating purposes, and whether exhaust steam can be used for those purposes.

i. Is water needed for other purposes than power, and in what quantities?

j. The social and sanitary conditions which make it possible to procure and keep good help.

k. The greater uniformity of speed with steam than with water power.

Except the last two, all the above items can be estimated approximately in money value.

The most valuable power is that one which has a nearly constant flow during a dry year, or one that can be made so by storage basins and requires no augmentation from other sources.

When the cost of steam power minus the cost of water power is a plus quantity, the value of the undeveloped power is represented by a sum of money which at interest will pay the difference.

Let us now consider the value of a power which is variable and which cannot be depended upon throughout the year.

We must here consider:

a. The maximum, minimum, and average quantity of water, and the length of time when there is no water.

b. All the other items which entered into the value of a uniform power.

c. The necessity, nearly always existing, for a supplementary steam plant.

The quantities and falls at different times determine the power. If there is liability to excessive rises in the river, the head is diminished by back-water and the power reduced. If the quantity of water is reduced below its normal flow, the power is reduced and it ceases altogether when the flow ceases. If the variation causes many days of

complete or partial shut-downs, the power will be valueless for most kinds of business unless supplemented by steam power, and if the total lack of water lasts for many days, the steam plant must be of the same power as the water power used.

We should then be at the expense of maintaining two plants and of running each a portion of the time.

The total cost of running both plants should be compared with the cost of producing steam power elsewhere, as in the case of a permanent power. But the cost should be modified as before for the difference in cost of freights, for any advantage to be derived for the use of water for other purposes than power, and for any other advantages or disadvantages attending the use of one or the other power.

The value of an undeveloped variable power is, therefore, usually nothing if its variation is great, unless it is to be supplemented by a steam plant. When so supplemented it is of value only when the cost per horse-power for the double plant is less than that of steam power under the same conditions as mentioned for a permanent power, and its value can be represented in the manner in which the value of a permanent power has been represented.

Let us now consider the value of a developed power on which money has been expended in the construction of a dam or canal, or both, and on wheel plant.

To determine the market value of such a power we must first consider the undeveloped power independently of the plant; and then determine the value of the improvements. The sum of both will represent the value of the power as developed.

Cases may occur where the value of the undeveloped power is a minus quantity, but where the value of the improvements more than makes up the deficiency, thus making the power of value in the developed state.

The value of a power depends, of course, upon the work which it does and not necessarily upon the cost of development.

The value depends also upon the character of the work done and upon the condition of the dam, canal and wheel plant. If any portion requires renewing soon, the value is lessened; and if a general renewal of all the plant is necessary, the value is practically the same as though it were undeveloped.

The value of the plant will be its cost, less depreciation, up to the point where the cost of water power equals that of steam power. Beyond this point the value of the improvements would not be represented by their cost.

The value of the improvements, if new, would be a sum such that the total cost of power should not exceed that of steam power.

The value of a developed water power is then as follows: If the power can be run cheaper than steam, the value is that of the power, plus the cost of plant, less depreciation. If it cannot be run as cheaply as steam, considering its cost, etc., the value of the power itself is nothing, but the value of the plant is such a sum as could be paid for it new, which would reduce the total cost of running to that of running by steam power, less depreciation. In other words, it is worth just what can be got out of the plant and no more.

If a portion or all of an undeveloped power is taken from the owner, a fair compensation for the power taken would be its market value. But in the case of a developed power, where a manufacturing plant has been established and business carried on, the damage may be more than the market value of the power taken, because of its effect upon the entire plant.

With reference to the paper presented this evening, I desire to say:

First. The power which is in the stream or which has been diverted from it is always, and necessarily, determined by some system of averages. These averages are very misleading, and the longer the period they cover the more attractive appears the water power. They suffice, however, to determine the *average* power diverted, provided they are used properly and not as in a case on which I recently testified, where the experts for the plaintiff included in the average every drop of freshet water and allowed for no waste at any other time.

The months should be arranged, not according to the calendar, but in the order of their dryness.

By taking the average for a series of years, including both dry and wet years, we should find a greater uniformity of flow; whereas, on the other hand, a comparison of daily averages would show much wider fluctuations.

It is the maximum fluctuations which must be used in determining the size of the auxiliary steam plant, while the average for a long period determines the average amount of power which must be supplied by that plant.

Second. There can be no comparison between a variable water power and a constant steam power until the water power is brought to the same basis by the addition of a supplementary plant.

By plotting the monthly flows and drawing a horizontal line to represent the average for the entire year, we shall find, above the line in the wet months, an area representing waste water, and below the line in the dry months, an area which shows the lack of power which must be made good in some way in order to have a constant power.

Third. Although it may be safe to use the Sudbury River observations in this neighborhood, it would not be so in a mountainous region where the streams are torrential, the flow-off quick and the pondage small, and where the relation of rainfall to flow-off would be very different from that on the Sudbury. In all cases the flow-off should be determined, if possible, and used rather than the rainfall.

If the flow-off is determined for a year or longer, and compared with the rainfall of that same period, some idea is obtained of the relation of rainfall to flow-off; and, having this relation, we may deduce the flow-off from the rainfalls of other years.

Fourth. Where the total head is divided between two or more falls, I think it wholly improper to add the falls together in determining the value unless the expense entailed by making them into one fall is offset against the value of the combined fall. With a high fall the cost of plant development per horse-power is less than for a low fall, and, therefore, the value per horse-power based upon the combined falls is greater than that of either of the separate falls, and too high a value is thus set on the property.

Fifth. The true value of a water power is its market value. The engineer may not, and probably does not, know all the items which go to make up the market value; but he should consider such a case as he would if he were engaged to look into and report upon the value of a power; and if he uses the right method, he can determine very closely the actual value of a property, at least as closely as the practical witness, so-called, who merely guesses that the market value is so many thousand dollars.

Sixth. If a man is carrying on a profitable business, and a portion or all of his power is taken away, the damage to him should be measured by what it will cost to furnish him with a new source of power and to maintain and run it, due credit being given, as is not usually done, for the cost of obtaining his present power. It is simply a case of market value of the whole property before and after the taking. If a man contemplated purchasing a property including a water power, and knew that very soon a part or all of the water power was to be taken away, he would deduct from what he considered the value before the taking, a sum which would cover the cost of furnishing a substitute power.

This method holds good up to a point where the damages reach the value of the entire property under consideration. When they exceed that value there is some fallacy in the method used, for certainly the damage cannot justly be greater than the total value of the property, and when damages are figured out, as they sometimes are, to as much as ten times the value of the whole property, the operation becomes an absurdity, and I do not see how an engineer can conscientiously testify to such values unless he would be willing to recommend a manufacturer to pay such prices.

By Lewis M. Hastings.—The method of taking the average yield per month is open to criticism, in that the *fluctuations* in the amount of power to be obtained from a fall are reduced in proportion to the length of the period taken, the longer the periods chosen in which to show the average flow, the more regular will the flow and the resulting power appear. In the periods usually chosen, of one month each, the *actual*

power obtained may, and usually does, vary greatly above and below the *average* shown. Now it is a well-established proposition that one of the important elements of value in a water power is its *regularity* or uniformity.

Mr. Samuel McElroy, in a paper on the "Water Power of Niagara Falls," says: "The relative value of water power depends on the quantity, head, and *regularity of supply*, and upon its purity."

Mr. Charles E. Emery, C. E., writing of the "Cost of Steam Power," says that "Water power ceases to be of considerable value when the *variation* in the power available forms a considerable proportion of the total power required."

This method of monthly averages gives apparent results in excess of what would be obtained in practice, for it assumes that the days of low power are reinforced from days of high power, and unless there is abundant storage capacity, this cannot be accomplished in fact. The only practicable way to obtain in practice anything like the *average* power shown is to supplement the water with steam in order to make up the irregularities. These irregularities are much more marked in small streams than in larger ones, so that the rule would seem to be that the larger the stream the more valuable it is for horse-power.

The most that can be said of this method is that it is the best available in the absence of data to give the daily flow and power.

Another element of uncertainty, and one in which the practice varies considerably, is to be found in the manner of using the water held in the pond to reinforce the natural flow of the stream. Some mills run during the 24 hours of the day, some run 12 hours a day, some 10 hours, some less.

Now it will readily be seen that the mill running 24 hours daily has little use for pondage and will have power dependent only on the natural flow of the stream. The mill running 12 hours, if the pond is large enough, can claim a power twice as large as the one running 24 hours daily, while a mill running 10 hours daily can develop a power 2.4 times the first, and so on. Thus, by simply shortening the running time of the mill, the power may theoretically be developed to an extent limited only by the capacity of the pond. In my own experience three different running times have been used at different mills. This is sometimes quite a serious matter, and some standard time ought to be adopted as a basis upon which all powers can be rated.

In regard to the *value* of water power, I find no reliable criterion or measure. That water power has not the value it once had is generally acknowledged. Mr. Edward Atkinson, in a discussion of "Mills and Mill Engineering," says in effect that water, as a motive power, has outlived its usefulness and that it is being superseded by steam. Each

power must be valued by itself, and all the elements of each, the cost, including the amount and regularity of power and the situation regarding markets, labor, freight rates, etc., must be considered.

The method of valuing water power by putting it on a coal basis has been excluded from the courts for some years. It is little less than absurd, for the very conditions which make coal high and steam expensive would make water power unavailable and of reduced value, the two working in an inverse ratio. A comparison of values is apt to be misleading, unless all the conditions are carefully considered. The only way to get a fair and common-sense valuation of the power, is first to determine as nearly as possible the *amount* of the power, and then to trust to the good judgment of business men or manufacturers familiar with the use and value of power.

Soon after the settlement of the case with Sibley, to which Mr. Kimball refers, the mill owners on Charles River, below Stony Brook, brought suit against the city of Cambridge for taking the water of Stony Brook and consequent loss of power in the river. Some points in this case were discussed in a paper read before the New England Water Works Association, but, as the case was quite different from the one above alluded to, I venture to introduce here the tables then presented:

Exhibit No. 1.

Showing Horse Power of Charles River at the Dam of the Boston Manufacturing Company in Waltham.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
	Rainfall collectible.	Amount collected and flowing off per month. (Area 184.78 square miles.	Amount flowing off per minute.	Amount of flow available for power in river.	Amount of flow not available for power.	Amount of pondage. (To be added to amount in Col. IV.)	Gross amount available for power.	Power with effective head of 11 feet. 75 per cent. efficiency at the wheels.
	Ins.	Cubic feet.	Cubic feet per minute.					Horse Power.
January .	2.005	860,700,000	19,281	18,000	1,281	22,400	40,400	630.24
February	3.206	1,376,260,000	33,831	26,000	7,831	22,400	48,000	755.04
March .	4.997	2,145,100,000	48,053	26,000	22,053	22,400	48,400	755.04
April . .	3.609	1,549,260,000	35,862	26,000	9,862	22,400	48,400	755.04
May . .	1.987	852,970,000	19,107	18,000	1,107	22,400	40,400	630.24
June . .	0.864	370,894,500	8,585	8,000	585	14,154	22,154	345.64
July . .	0.335	143,807,000	3,221	3,000	221	5,266	8,266	128.90
August .	0.549	235,670,000	5,279	5,000	279	8,777	13,777	214.90
September	0.457	196,180,000	4,541	4,500	41	7,961	12,461	194,40
October .	1.053	452,030,000	10,126	9,500	626	16,677	26,177	408.36
November	1.617	694,130,000	16,068	15,500	568	22,400	37,900	591.24
December	1.940	832,790,000	18,656	18,000	656	22,400	40,400	630.24

12)6,039.28

Average daily horse-power for the year = 503.27

Exhibit No. 2.

Showing Horse Power of Charles River at the Dam of the Boston Manufacturing Co., in Waltham, after Diverting all the Water of Stony Brook.

	I.	II.	III.	IV.	V.	VI.
	Rainfall collectible.	Amount flowing off area 161.78 square miles.	Amount of flow in river available for power.	Amount of pondage to be added to Col. III.	Gross amount available for power.	Power with effective head of 11 feet. 75 per cent. efficiency at the wheels.
	Inches.	Cubic feet per minute.				Horse Power.
January	2.005	16,871	15,750	22,400	38,150	595.14
February	3.206	29,600	22,750	22,400	45,150	704.34
March	4.997	42,046	22,750	22,400	45,150	704.34
April	3.609	31,379	22,750	22,400	45,150	704.34
May	1.987	16,718	15,750	22,400	38,150	595.14
June	0.864	7,512	7,000	12,385	19,385	302.41
July	0.335	2,818	2,275	4,958	7,233	112.83
August	0.549	4,617	4,375	7,680	12,055	188.06
September	0.457	3,973	3,938	6,966	10,904	170.10
October	1.053	8,860	8,313	14,592	22,905	357.32
November	1.617	14,060	13,563	19,600	33,163	517.34
December	1.940	16,324	15,750	22,400	38,150	595.14
						12)5,546.50

Average daily horse-power for the year = 462.20

Horse-power of Charles River, including Stony Brook (Exhibit No. 1) . . . . = 503.27 H. P.

Horse-power of Charles River, excluding Stony Brook (Exhibit No. 2) . . . . = 462.20 H. P.

Net loss of power as shown above = 41.07 H. P.

Exhibit No. 3.

Showing Horse Power of Charles River, allowed by the City of Cambridge as lost to the Boston Manufacturing Co., by taking the water of Stony Brook.

		IV.	V.	VI.	VII.	VIII.	IX.	X.
	Columns I, II, III, IV and V, same as shown in Exhibit No. 1.	Amount of flow in river available for power.	Amount of flow not available for power.	Amount of flow wasted over dam as shown by Boston Mfg. Co.'s record.	Flow of Stony Brook, 23 square miles.	Estimated loss for power in natural flow of river.	Estimated loss (Col. VIII) developed by pondage.	Net horse-power on fall of 11 ft. 75 per cent. efficiency at the wheels.
		Cubic feet per minute.						Horse Power.
January		18,000	1,281	5,215	2,180	...	...	...
February		26,000	7,831	10,800	4,092	...	...	...
March		26,000	22,053	13,830	5,005	...	...	...
April		26,000	9,862	11,570	3,889	...	...	...
May		18,000	1,107	6,715	2,260	...	...	...
June		8,000	585	1,907	1,065	533	1,475	23.01
July		3,000	221	68	549	549	1,572	24.54
August		5,000	279	380	698	698	1,923	30.00
September		4,500	41	891	652	652	1,805	28.15
October		9,500	626	1,069	959	959	2,642	41.22
November		15,500	568	2,294	1,700	850	2,449	38.21
December		18,000	656	4,353	1,989	...	...	...
								12)185.13

Allowed loss of horse-power in Charles River, by taking Stony Brook = 15.43

The method followed in preparing Exhibits Nos. 1 and 2, is the same as shown in those of the Sibley case,—the only difference between No. 1 and No. 2 being the reduction in the drainage area, due to subtracting that of Stony Brook from the full area of Charles River. By subtracting the power obtained in Exhibit No. 2 from that obtained in No. 1 the theoretical loss of power is given as 41.07 horse-power.

This is interesting as showing the effect of the *size of the pond.* Here the river was deprived of one-eighth of its drainage area by

diverting Stony Brook, with its twenty-three square miles of area, and at first thought, it would appear that the total power of the river must be reduced in like proportion,—or 62.91 horse-power. Owing, however, to the lack of storing capacity in the pond, much of the reduction in flow, caused by the reduction of area, is taken out of the water which would otherwise be wasted during the flood seasons of the year; so that instead of a loss of 62.91 horse-power there is a loss of only 41.07 horse-power.

This loss of 41.07 horse-power would be the loss caused by the use and diversion of the entire yield of Stony Brook; and as this is a practical impossibility, and as it was not believed that any such loss really did or would occur, a new study of the case, with additional data, was given it, and the results are shown in Exhibit No. 3.

The data given, up to Column 6, are the same as those in Exhibit No. 1. Column 6 shows the average amount wasted at the dam at Waltham during ten years. Column 7 gives the flow of Stony Brook. From a comparison of Columns 5, 6 and 7 the conclusion was drawn that during the months of January, February, March, April, May and December, more water would be wasted than the entire flow of Stony Brook; that during June and November one-half the flow of Stony Brook would be lost, and that during July, August, September and October the entire flow would be lost to the mills.

These quantities, shown in Column 8, developed by ponding in Column 9, and reduced to horse-power in Column 10, amount to 15.43 horse-power for the year, and this was the amount allowed by the City as lost to the mills.

It may be of interest to state that whereas the companies on Charles River, affected by the taking of water in Stony Brook, claimed a loss of 200 H. P., valued by them at $160,000, the award of the Commissioners for the total damage was $15,000.

By Richard A. Hale.—In the paper we have just heard, Mr. Kimball has made a very interesting presentation of the subject; but there are a few points which may yet be profitably enlarged upon. The problem of the value of a stream for water power embraces many elements which vary with each individual case. The character of the water-shed, whether steep and rocky, permitting the rainfall to flow off rapidly, or flat and wooded, with ponds and lakes which retain the heavy rainfall and act as regulators to the stream, is an important factor.

The storage available above a dam where water power is located should be known, and the limits within which it can be practically used without seriously affecting the head acting on the wheels. The deter-

mination of the flow of the river through the different seasons is of great importance, and, if known by actual measurement for a series of years in connection with the rainfall, forms a valuable index in ascertaining the power available. Often these are not to be obtained, and comparisons with known measurements on water-sheds of similar character with known rainfall have then to be made.

The measurements of the Sudbury River, covering a long series of years, are of great value to engineers in estimating yields in this section of the country. One point may be mentioned in regard to the use of monthly averages of yields in computations of this character. It may happen that on small water-sheds a sudden and severe storm may produce for a few days a large flow which cannot be retained by storage, and a large amount may thus be wasted. This quantity, if averaged with dry times in the month, would be indicated in the monthly average as available for power, whereas quite the contrary might be the fact. In regard to the fall available, there is quite a difference between the falls claimed by Mr. Sibley and that found by Mr. Hastings in the estimates.

The conditions of use of the power show an actual use of about 24 feet, although 34 feet is claimed as a total fall by the mills. If, with reasonable expenditure, the fall could be increased from 24 to 34 feet, and even a portion of this 10 feet utilized, I think it might be included in the available power claimed at the mill.

In regard to the waste water unavailable for power, no fixed rule can be followed in regard to the months in which it should be applied. In a case of the Boston Manufacturing Company, on the Charles River at Waltham, against the city of Cambridge, it was conceded that the power of the river had been developed to its greatest capacity, and that the company had been increasing its steam plant in preference to making any increase in its water plant. The amount of steam power used was about four times the amount of water power which could be developed by the wheels.

The flow of the stream, deduced from the Sudbury River results, indicated that for four months of the year surplus water was passing that could not be used by the full capacity of the wheels. This fact agrees with Mr. Francis' statement that water is wasted during three or four months in the year.

In the case just cited the method of determining the loss of power was to find the flow of the Charles River before Stony Brook was diverted and after the diversion. It was also ascertained in what months the loss of power would occur, and what actual power was lost by the diversion. From the quantity of water that was diverted during those months when the concentrated flow in twelve hours was less than the

full wheel capacity, the actual horse-power that could be obtained on the wheels in use in the mill was determined. This was found from the size of the wheels, the opening of the gates and the percentage of useful effect obtained.

From this method of procedure an average daily loss of 14 horse-power per year was found, whereas 130 horse-power was claimed. The fact of admitting that the water power was fully developed, simplified the problem.

I think that Mr. Sibley's computation of power by estimating a storage of night flow for all months in the year is somewhat excessive. During the freshet months, when all streams and ponds are filled to overflowing, much water is necessarily wasted, unless the storage capacities are unusually large. Keeping in view the situation of the dams, I should say that storage should also be taken into account between May 1st and October 1st; for during the dry months the ponds may, with careful management, be drawn down to a certain point and filled up by the night flow for a full pond the next morning. There must be many times between October and May when night storage is impossible.

In regard to the supplanting of water power by steam power, experience at Lawrence has shown that additional water wheels amounting to 1,200 horse-power have been added during the past year, that there is a prospect of further increase, and that during the last three years many old water-wheels have been removed and replaced by new and modern wheels of 1,000 horse-power greater capacity.

In regard to the relative cost of maintenance of steam and water power plants, I may say that the cost of maintenance for new wheels set on horizontal shafts is but light. With wheels set on vertical shafts breakages of gears may occur and the steps wear down, but even these accidents are of infrequent occurrence in well-managed mills.

In the case of steam plants the cost of maintenance must vary greatly. In some establishments known to the writer the bills for repairs must form no inconsiderable item.

On a water power of the size of that under discussion steam power must certainly be employed to supplement the water power. The damage due to the diversion is the value of the coal and supplies used, with an allowance for the depreciation due to the increase of the load carried by the engine.

By Waldo E. Buck.—In listening to Mr. Hastings I noticed that while one-eighth of the total water-shed has been appropriated by the city of Cambridge, only 15 horse-power, by his computations, is taken from a total of a little over 500 horse-power. Suppose now that a second

municipality should appropriate another eighth part of the drainage area above the dam, it would follow by a similar calculation that more than 15 horse-power would be taken out in the second instance, since taking out another eighth of the water-shed would tend to affect the flow over a still greater period than the abstraction of the first eighth ; for it is easy to see that you might take eighths until you had appropriated the entire stream.

Mr. Hastings: I took out the top eighth.

Mr. Buck: Yes, you were fortunate in that. The Lake Company, of which I was agent for upward of six years, owns and controls the dams at the outlets of various reservoirs in New Hampshire. I can only give you the data from memory and in round figures, but I think they will come very near the truth.

The reservoir dams owned by the Lake Company, when I became its agent, were located at the following outlets: Smith's and Crooked ponds at Wolfboro, Winnipiseogee Lake at Lake Village, Sanbornton Bay at East Tilton, Squam Lakes at Ashland, and New Found Lake at Bristol.

The areas of these lakes were about as follows:

Smith's and Crooked Ponds	4	square miles.
Winnipiseogee Lake	$71\frac{3}{4}$	" "
Sanbornton Bay	$7\frac{1}{4}$	" "
Great and Little Squam Lakes	$11\frac{1}{2}$	" "
New Found Lake	$7\frac{3}{4}$	" "

In only one instance was it possible to make anything like complete storage in any of these reservoirs, and that was in the Squam Lakes. The dam there will not fill and waste water more than once in about four years.

At the Winnipiseogee dam there will be a waste, on the average, two years out of three, and during one year in three the dam will hold all the water that comes.

As a storage reservoir Sanbornton Bay is not of much account, for the bed of the river is so shallow above the dam that the bay can be drawn down but little. As a means of regulating the flow in the river, however, it is quite important.

The power at Laconia and Lake village is used during the day and the water held back during the night. At and below East Tilton the power is used continuously for twenty-four hours, and having this large storage basin between it is practicable to do this without inconvenience to any parties on the stream.

New Found Lake wastes water every spring.

The water-shed of New Found Lake is about 90 square miles, and the area of the lake is $7\frac{3}{4}$ square miles.

The control of the dam at the outlet of New Found Lake is from five to six feet.

The area of the Winnipiseogee water-shed is 366 square miles, which is about five times the area of the lake, and the dam controls about four feet, *i. e.*, extreme low water in the lake would be at a level of four feet below the top of the dam, but it is seldom drawn to this point.

The area of Winnipiseogee is such that a draft of 1,930 cubic feet per second for twenty-four hours will lower it one inch.

As a convenient means of computation, I used to carry these figures in my head rather than the areas of the lakes.

A draft of 197 cubic feet per second would lower Sanbornton Bay one inch in twenty-four hours.

The ratio of the flow-off to the rainfall in these drainage basins would, I think, be a little higher than in such basins as the Sudbury River, for which figures have been presented in the table accompanying the paper of the evening.

The average rainfall is forty-five inches, or very near that given in this table.

From observations which I made on the flow at the dam during one year, which were approximate only, but probably quite near the truth, I found the flow-off in one month as high as 135 per cent. of the rainfall. Of course the figures in the table presented, showing 106 and 115 per cent. of flow-off, were due to water derived from melted snow. In the Winnipiseogee basin this is a larger factor than in the Sudbury basin, and our largest flow-off would come about a month later than in the Sudbury basin, bringing it in the month of May instead of April, as the season is later in that locality.

The ice usually goes out of Winnipiseogee Lake about the first of May or the latter part of April. This year it was as late as the 10th of May.

It is a singular thing that the ice all disappears in one day, even when the lake is covered with ice eight or ten inches thick. This is undoubtedly due to the action of the sun and the wind combined, for the ice becomes honey-combed by the action of the sun and broken up by the wind.

The snow-fall there is almost a valuable reservoir in its action, coming along as late as it does.

Usually in seasons of flood the water is down to the top of the dam by the middle of June probably, and we then begin to draw on the storage area of the lake.

These reservoirs were developed by the owners of the water power

at Lowell and Lawrence. They expected to get surplus water in dry seasons of the year for the special benefit of the Merrimack River, and estimated as well as could be done in those times. The work was begun in 1846.

It was necessary to furnish supply to the various owners of water powers on the streams fed by these lakes; and it was the aim also to retain some surplus which could be drawn at low stages of the Merrimack.

At Winnipiseogee a surplus was obtained. At New Found Lake no settlement was ever made with the other mill owners, so that the right to discharge the surplus water was never thoroughly established.

At the Squam Lakes definite settlement of the rights was made with the mill owners, but unfortunately the mill owners were allowed practically all that the lakes would furnish. The settlement called for a flow of 75 cubic feet per second throughout the twenty-four hours, and this being from a water-shed of only 56 square miles, it would practically exhaust the available supply.

At Winnipiseogee the settlement was 250 cubic feet per second. This left some margin for a surplus, which would on an average be about 12 per cent. of the storage of the lake.

The property at the outlet of Smith's and Crooked Lakes I sold at one time together with a tract of land worth perhaps $2,000. The entire property was sold for $6,000. The water powers sold would probably equal the one mentioned in Mr. Kimball's paper and would be more reliable, although they are located more than 100 miles from Boston, but near a line of railway.

The entire property at Lake Village was sold by the former owners, and the price realized at that time was about $58,000, which included four mills, not in very good condition, and the entire water power incident to the dam, with the exception of two permanent leases. This was a far better power than the one mentioned in Mr. Kimball's paper, and was well located in the heart of a flourishing village on a line of a railway.

That privilege has a fall of from 8 to 12 feet, according to the condition of the lake, and the available flow is about 400 cubic feet per second, or, if used during the day only, 800 cubic feet per second.

These figures, of course, indicate that such properties as are here considered cannot be sold at any such figures as are presented in the tables of Mr. Kimball's paper.

One trouble with estimates of this sort lies in a consideration which Mr. Francis, not being on the right side of the case, did not go into, and that is this, viz.: that in order to use power which he estimates to be in the privilege it is necessary to put in proper appliances. If, for example, he figures the power to be worth $66,000, and it is necessary

to spend $50,000 in appliances in order to use it, the balance of $16,000 more nearly represents the value of the undeveloped power. This point has been brought out by Mr. Charles T. Main in his discussion of this paper.

Generally speaking, these were the results obtained with the New Hampshire reservoirs with quite complete storage capacities, and from the experience with these reservoirs it is safe to reckon upon a steady flow of one cubic foot per second for each square mile of water-shed. This result was very considerably exceeded in the Squam Lakes, which I think practically never ran below the flow of 75 cubic feet per second from a water-shed of 56 square miles, but in this instance the storage is very complete.

By Prof. George F. Swain.—The subject of the paper has already been so ably discussed, and the general principles involved are so simple, aside from the special peculiarities which each individual case will present, that I hesitate to add to the literature of the subject, since I can contribute little or nothing essentially new. Possibly, however, further agitation of the subject is necessary before the popular idea is uprooted that the value of a water power is measured by the cost of replacing it. It is unnecessary to add to the illustrations showing the fallacy of this assumption, for it is perfectly clear that there is no more reason in such a basis of value than there would be in the proposition that when a man's finger is cut off in a railroad accident the measure of damages is the cost of replacing the finger. When a water power is condemned and seized for public purposes, it is to be considered as done from public necessity, and the plain basis of damages is the actual value of the power to its owner, in its existing condition. Sentiment does not enter to any considerable extent into this question. A water power has no sentimental value, like that possessed by a piece of bric-a-brac, which a man may value because it has descended to him from his great-grand-mother. The problem before the engineer is simply to determine the fair present value of the power to its owner.

In determining this the first step will, of course, be to estimate the amount of power diverted. In doing this, it will not always be wise, even in this section of the country, to use the ratios found from the Sudbury River records. Drainage areas differ so greatly in topographical and geological features that two adjacent streams may be entirely dissimilar as regards the ratio of flow to rainfall and the variation of flow through the year. We are all acquainted with streams lying within a few miles of each other, yet totally dissimilar in character. In making such an estimate nothing can replace experience and judgment,

together with an intimate knowledge of the water-shed under consideration, but the experienced engineer can, without difficulty, make a sufficiently close approximation. We must realize, however, that such an estimate is simply an approximation, and that it is not necessary to carry figures to hundredths of a horse-power or of a cubic foot per second. There will be found, in the minds of experts and referees, so much greater difference of opinion in the later consideration of the question regarding the money value of a horse-power, that the error in the estimate made by a careful engineer will be small in comparison.

Having made his estimate of the power diverted—in each month of an average year, and perhaps in each month of a dry year—the next problem is to determine the value of this diverted power. In this connection it may be well to classify in a general way the cases which may occur, somewhat as below. It will be necessary for the engineer to decide into which class the case under consideration falls, and hence it will generally be necessary for him to make some estimate relating to the cost of steam power.

The power is

- A. UNUTILIZED.
  1. Steam power can be developed more cheaply than water power on the site.
  2. Steam power can *not* be developed as cheaply as water power on the site, but can be developed more cheaply in another suitable locality.
  3. Steam power can *not* be developed as cheaply as water power, either on the site or elsewhere.
- B. UTILIZED.
  1. The power utilized is *not* affected by the diversion. *No* steam power is used.
     (*a*) Additional steam power is cheaper than water.
     (*b*) Additional steam power is dearer than water.
  2. The power utilized is *not* affected by the diversion. *Steam power is used.*
     (*a*) and (*b*) as above.
  3. The power utilized *is* affected by the diversion. *No* steam power is used.
     (*a*) and (*b*) as above.
  4. The power utilized *is* affected by the diversion. *Steam power is used.*
     (*a*) and (*b*) as above.

In the case A1, in which steam power can be developed and maintained on the spot at a less capitalized present cost than water

power, it is perfectly clear that the water power possesses no value whatsoever as a power. It may be valuable as a site for storage, or for other purposes, but for power it is valueless. It is like a mass of rock containing a trace of gold, the cost of extracting which exceeds its value when extracted; the rock may be valuable for road metal or for ballast, but it is valueless as ore. It is unnecessary to say that in this and other cases we should estimate the sum which would suffice to develop and maintain forever a steam or water plant. The only question under this head is as to the amount of power which should be estimated on, whether the average through an average year, or some other quantity. This will depend somewhat upon the amount of water diverted. If the whole stream is taken, it seems to the writer that the proper basis is the ordinary summer flow, since this is all the water power that would be practically available unless supplemented by steam.

The cases A2 and A3 lead us to other considerations, which will depend upon the special features of the locality, and which we need not discuss exhaustively. The essential point involved seems to be that the cost of water power at the site in question may fairly be compared with the cost of steam power at some other point, where coal is cheap, and transportation facilities good, and that these transportation facilities should be duly considered. In the case A2, the water power will generally be valueless; and in A3 its value will depend upon these other considerations. It will also be fair to compare the prices at which water power can be obtained at other localities, as at Lawrence, at Holyoke, or at points in Maine or in the Western States. It makes no difference whether the rates for water power at these places are low for the reason that the companies leasing or selling power expect to make money on the sale of *land*, unless this renders unduly expensive the acquisition of a site for the manufacturing establishment. Here is an undeveloped power. The simple question is, What is it worth? If I can go to Turner's Falls and get all the power I want at $7.50 per annum per horse-power, with a site for building on terms which, considering transportation facilities, are as low as at the site in question, and if both places are equally suitable for my mill, I certainly would not pay more than $7.50 here. It is clear, however, that no absolute rule can be laid down for all cases, but that every circumstance bearing on the case must be duly considered.

The case of a utilized power is much more complicated to deal with, and its full discussion will not be attempted here. The first question to be settled is, whether the utilized water power is interfered with by the proposed diversion, and, if so, to what extent. This depends upon the engineer's estimate of the flow.

If the utilized water power is not affected by the diversion, even during a dry year, then the *power diverted* stands on the basis of an unutilized power, but its treatment is modified by the fact that a portion of the total power is utilized, and much will depend also upon whether the existing mill is provided with steam power. Generally there will be either no steam power or else a large amount of it, since in the case assumed there is always a waste of water. If, under these circumstances, additional steam power, in amount equal to the power diverted in ordinary summer flow, could be provided more cheaply than the additional water power (Case B1*a*), there should be no damages. If the reverse is the case, steam power being estimated at the site (Case B1*b*), the measure of damages may be the cost of providing the additional steam power above that required to provide the additional water power. Some regard should be had, however, in this case as in others, to the *probability previously existing of the development of additional power.* In other words, the damages above mentioned will be too large unless it is certain that additional power would be at once developed if no diversion occurred; and, strictly speaking, the damages should be a sum which, if placed at interest, would, *at the time when the power would have been increased if the diversion had not taken place,* become sufficient to provide for the additional cost of steam power. This introduces an element of contingency which cannot be estimated; but it is worth while to remember that any estimate is too large which is based on the present cost of supplying power which would not naturally be called for now if at all.

In case B2, where steam power already exists, the damages will in general be the excess of the cost of getting the additional power by steam above that of getting it by water. If the amount is small, no change in engine may be required, and it will then simply be necessary to capitalize the cost of the additional coal needed, allowing also a proportion of the repairs and renewals of steam plant, and deducting the capitalized cost of developing the additional power by water. If the result is negative, there should be no damages. If much additional power is required, it may be necessary to instal an auxiliary plant to supply this; or to replace the engine with a larger one, and put in another boiler. In all these cases the items of attendance, boiler-house, etc., entering into the estimate must be properly taken.

If the existing utilized power *is* affected by the diversion, then so far as this effect goes, the damages should be the excess of the cost of replacing it by steam above that of maintaining it by water, while, so far as concerns the remainder (*i. e.*, the portion which could be diverted without affecting the power utilized) the case is the same as already discussed.

The statements here made are subject to modification in special cases, since no general rules can be laid down; but they express in a general way the writer's view as to the mode of approaching the subject. Especially with regard to the amount of power to be estimated—*i. e.*, whether the average through the year, or some other quantity, should be taken as a basis—local circumstances may affect the case.

Before closing this already too lengthy discussion, mention may be made of the fact that many engineers, in considering this matter, treat each power as though the question were one of developing it economically to its fullest capacity. To effect such development, it is of course necessary to supplement the water-power plant by a steam plant to be used during only a part of the year. The case thus becomes one under B2 or B4. This does not appear to the writer to be in all cases quite correct. For instance, suppose a stream furnishes at all times a power of 50 horse-power, and that on it is a mill using 45 horse-power continuously; suppose, now, that a branch is diverted, the flow from which yields at the minimum 3 horse-power. Now, this power is, of course, not fully developed, and no steam power is used. It comes under Case B1; and it appears to the writer that in estimating damages it is fair to suppose that the mill owner might desire to get just 3 horse-power additional continuously throughout the year. However, cases frequently occur in which the engineer must consider the question of a double power, the steam to be used during only part of the year.

This contribution does not pretend to be by any means a complete discussion of the subject. Many elements entering into the problem have not been even mentioned—such, for instance, as the effect of requiring steam for heating in winter. So far as it goes, however, it may aid somewhat in systematizing ideas upon this important subject. That this is necessary, is made evident by some recent papers which have appeared, as well as by the positions taken by various engineers when called upon as experts.

By Clemens Herschel.—I have been asked to call attention to the fact that during periods of low water, small streams have, in proportion to their respective drainage areas, a smaller yield than large streams; and to state the reasons for this. That such is the fact must upon a little examination be evident to every one. The minimum discharge in cubic feet per square mile of drainage area becomes less, other things being equal, as the total drainage area becomes less, until, in the case of drainage areas of one, two or more square miles, this minimum discharge is zero for months at a time.

And the reason cannot be very obscure. Large streams are to a

great extent fed by springs contributing directly into their deep cut channels; while small streams have little or no aid from such underground natural drains.

The study and classification of streams and of their stream-flow has been much hindered and obscured by the useless simultaneous consideration of an alleged or assumed direct dependence of the stream-flow for a month upon the rainfall over its drainage area for the same month; whereas if more attention had been given to a study and proper representation of stream-flows, we should all much better understand and appreciate how stream-flows differ as between different rivers, and vary from day to day and from year to year upon the same river. I beg to refer in this connection to some remarks of mine made in 1878, and reported with several diagrams of stream-flow in the *Transactions of the American Society of Civil Engineers* for that year; also to my discussion of the paper on "Rainfall and Stream-flow," read May 17, 1893, before the same Society.

By Joseph P. Frizell.—In England it was for a long time the practice to reimburse mill owners in kind for water diverted from their mills for the use of towns. In other words, the mill owners were given a share of the flood-water of the stream, which was impounded in storage reservoirs. To some extent this practice still prevails there.

When the original Cochituate system for Boston was constructed, an attempt was made to apply the same method.

It has not, however, met with favor, or with extended application in this country. This fact is to be ascribed to changes in the conditions under which mills are now operated. At the time I speak of, mills running by water ran *wholly* by water. Their machinery was proportioned to the *milling stage* of the stream. They required compensation water when the stream was below that stage, and they were in no way injured by the diversion when it was above that stage. Under present conditions, steam being very generally used in connection with water power, a mill can profitably use the flow of the stream to an extent far above the milling stage, thus greatly prolonging the time during which the diversion acts injuriously; in other words, existing conditions greatly diminish the volume of water available for impounding, and increase the demand for impounded water.

Moreover, in suits for damages arising out of the original Cochituate takings, the claimants contended that the reservoir method was no legal compensation. "The city of Boston," they said, "is very kind to construct these reservoirs for our use, and it has our thanks for its liberality; but we are entitled to claim, and do claim, the identical water which the city has diverted from us, or, in default thereof, adequate

compensation." A contention, as I am told, not wholly without warrant of law, unreasonable as it may appear.

It has thus become, in this country, the settled practice to demand cash damages in all cases of diversion of water, and the measure of damages usually claimed is the cost of replacing the lost power by the addition of steam power.

This rule is by no means one of universal application. It must bend to special circumstances. It applies in full force to the case of a mill privilege which has become the seat of an active and profitable industry. The owner of such a privilege, losing his water power, must supply himself with steam or discontinue business, and there can be no question of the justice of his claim for compensation on this basis.

There are other cases to which the rule has no application whatever, viz.: an abandoned mill privilege, where the water runs to waste and has so run for years. The settlement of damages in this case involves no assumption of replacement by steam or any other means of generating power. It presents simply the question of the value of unapplied water power.

The above are the two extreme cases. Many cases—in fact, the majority of cases—are intermediate between the two, partaking in part of the character of both. In some cases, while the water power is of considerable extent, the industry dependent on it is of trifling importance. In such cases the computation of damages on a steam basis would lead to a sum greatly in excess of the market value of the property, and would thus make the rule manifestly inequitable. Almost every case of this kind that arises is in some degree a case *sui generis*, and no satisfactory rule of universal application can be established.

By Marshall M. Tidd.—I have read with interest the paper of Mr. Kimball upon the value of water power, and the remarks of Mr. Main and of the other gentlemen who have spoken upon that subject, particularly because the paper of Mr. Kimball, upon which this discussion is brought about, is based upon the case of the Sibley Mills against the city of Cambridge, in which I had occasion to testify, and for the first time was radical enough to say that the power had no value whatever; but as the gentlemen who have spoken upon the matter, including Mr. Kimball, have all agreed substantially upon the ground which I took at that time, and have fairly covered all that I could say in the matter, there is but little left for me, except to ask the gentleman who wrote the paper how he, as one-third of the Commission, could reconcile the views expressed in this paper with the award of $11,000 damages. It seems to me that the fact that the mill stood for fifteen years within 300 feet of the Fitchburg Railroad and within twelve miles of Boston, without turning a wheel, would be sufficient evidence of its absolute lack of

value. I am aware that in reply to my statement in that case it was argued that the proprietor was a crank and therefore would not run the mill as other people would have done, but to my mind the fact of his letting it lie idle was evidence that he was not a crank, but had a a level head.

There was a time, long years ago, before the advent of steam as a successful motive power, when water and wind were the only powers that we had to use. In those days the use for mills was principally confined to the sawing of lumber and the grinding of corn, which were the prime necessities of the people. At that time this kind of industry was encouraged by the State, and the decisions of all courts in cases where the value of the power was involved were no doubt fitted to the circumstances of the times, but they are not fitted to those of to-day, although they are the basis upon which recent decisions have been made. It seems to me that there ought to be some new decisions from our courts, more nearly in accordance with the uses and public convenience of the present day than were the decisions of the courts of one hundred years ago. At that time water had no value except for purposes of power and navigation, and, as far as I can learn, very little of it was used even for drinking, and perhaps less for washing, but to-day water has many other and greater values than at that time. The evidence of the departure of the values of water powers may be seen all over New England to-day in the abandoned dams and mill privileges on nearly every stream. The use of motive power is now confined principally to manufacturing in fulfillment of contracts where the goods must be furnished at whatever season they are called for and furnished promptly, and as all water power is uncertain and is available only in certain short periods of the year, it has become necessary in all of the larger powers to supplement the water power with steam to be used in freshets, when the power is rendered worthless by the back-water, or in dry seasons, when no water is available for power. Steam is largely used in manufacture for other purposes than power, as in heating and drying, etc. Therefore the mill must have boilers, and these boilers must be fired constantly for those purposes. Now, when the mill is to maintain this steam plant and keep steam on the boilers, the cost of the power is simply the cost of the additional coal used for power over that for heating. Under these circumstances it is cheaper to run by steam altogether, particularly as we must go far away from the centers of trade in order to get the water power. The freight on the raw materials shipped to such distant points, and that on the manufactured materials back to market cost more than the water power is worth.

I am fully aware that much stress has been laid on the value of water power for use in the generation of electricity for lighting purposes, but I am unable to see why the manufacture of electricity is not just as

much governed by the laws of supply and demand as is the manufacture of any other commodity which we use, or why water power should be of greater value for that purpose than for any other.

A case in point may be found in the town of Weymouth, where the Weymouth Iron Co. had a mill with fifty feet fall and a large pondage, with a good water-shed to furnish the water. This company went into insolvency some seven or eight years since, and to-day the power lies idle on the line of a railroad, the track running into its ground, which the assignee has ever since that time been vainly endeavoring to sell. In the meantime, an electric light plant, run by steam, has been built within 1,000 feet of this water power, which lies there awaiting a purchaser. It seems to me that this case is a sufficient reply to the argument for the value of water power for electrical purposes. In the town of Braintree, on the Monatiquot River, there is a water power which was washed out by a freshet ten or twelve years since. The proprietor has not considered it worth while to rebuild, and the water is running waste there to-day.

My experience in the estimation of these values has taught me that the only real value existing in these water powers is the chance of unloading them upon the towns which have arrived at the necessity of building water works. I am aware that it is often said that the larger water powers like Lowell, Nashua, Manchester and Lewiston are large enough to have a fixed and permanent value, but I am also aware that all of these mill plants, in order to run full time, have been obliged to add steam power to their plant, and I feel confident that if the men who originally put the money into those places to build them, had that money to-day, they would never put it into any such enterprise; but, if they proposed going into manufacturing, would certainly do as they have done in Fall River and New Bedford—they would build their mills convenient to the market and to the sea, and run them by steam power.

By L. Frederick Rice.—It seems as though the great diversity in estimates of value of power diverted (although those estimates are without doubt honest) affords a strong reason for doing away altogether with the presentation of expert testimony by or in behalf of the parties in litigation, a reform which has been advocated by a number of gentlemen in years past.

It seems to me that the gentlemen who testify as experts, for one side or the other, in such cases, are very much in the position of members of an orchestra. They all assist in swelling the volume of sound, and those especially expert may be called upon for solos; each takes his respective instrument (possibly several take the same instrument), they start with the same tune or theme, and each plays his variations

according to his skill. It is honestly rendered music, each performer has played his part in an unexceptionable manner, and those in the audience have been entertained—but has anything been added to their knowledge of music?

Is a knowledge of the extent of damage done to a party by the diversion of a portion of his water power, attained any more readily with the assistance of expert engineering testimony than it would be in some other way?

Each expert studies the problem honestly, faithfully and diligently, but necessarily with certain preliminary assumptions. Granting these assumptions, accurate or easily demonstrated conclusions are reached, but unfortunately the conclusions are not conclusive, for they do not coincide. Each expert very naturally makes assumptions which, it is to be presumed, are not unfavorable to his clients, and the variance in the assumptions fully accounts for the difference in the conclusions.

It has been argued that expert testimony should be called by the court, and that questions of law should be kept distinct from questions of engineering—engineering experts being consulted *by the court* as to the bearing of facts in evidence. In other words, the lawyers should present to the court evidence as to the facts in each case, and the court should then ask the engineering expert as to the conclusion to be drawn from those facts.

It may even be claimed, in many cases, that the question of damages by the diversion of water may be best settled *without the testimony of engineers*, by determining the *difference in the price* for which the entire property in question could be sold *before* and *after* such diversion.

In a case which has been alluded to this evening, expensive buildings were commenced upon a water privilege, but were never completed. It is a reasonable assumption that they would have been finished and operated and the power utilized, if the operation had promised a profit, or that other parties would have bought, finished and operated the plant if they had seen any money to be made by so doing. But to operate so extensive a plant would probably have required more power than the water alone could supply. Supplementary steam power would be necessary, and it is evident that no one is willing to incur the expense necessary to provide such steam power, or to complete the buildings so as to utilize the water power alone.

How much or how little would be the damage actually caused by the diversion of a part of that water which is unused because it cannot be used profitably?

Is not the true measure of the damage caused by the diversion, the price which the property would bring if put up for sale to-morrow, with all the water running as it now is, unutilized, or with one-quarter or one-half less water, likewise unused?

SEWAGE DISPOSAL WORKS, CANTON, OHIO.

By L. E. Chapin, Member of the Civil Engineers' Club of Cleveland.

[Read December 12, 1893.]

The city of Canton, with a population of 32,000 and an area of 7 square miles, has a storm-water system of sewers for the removal of all storm water, and into this system no household wastes of any description are admitted. These storm water sewers discharge into the two branches of the Nimishilla Creek by the most direct and accessible routes.

SANITARY SEWERS.

For the removal of household wastes a separate system of sewers is used, into which no rain-water or elevator water is discharged. The general plan of this sanitary system contemplates the sewerage of the entire city by systems of mains, submains and laterals, varying from 6 to 20 inches in diameter, and of vitrified salt-glazed sewer pipe. The minimum grades range from 1 foot in 100 for the 6-inch laterals, to about 0.2 foot in a hundred for the 2C-inch main sewers.

FLUSHING.

All laterals are provided at their upper ends with automatic flushing-tanks, and a frequent and regular cleansing of all sewers is thus insured. The flush-tanks are in the main equipped with the Rhodes-Williams automatic siphon. Some sixty siphons of this pattern are in use, as well as eight Field-Waring siphons and one Rosewater siphon.

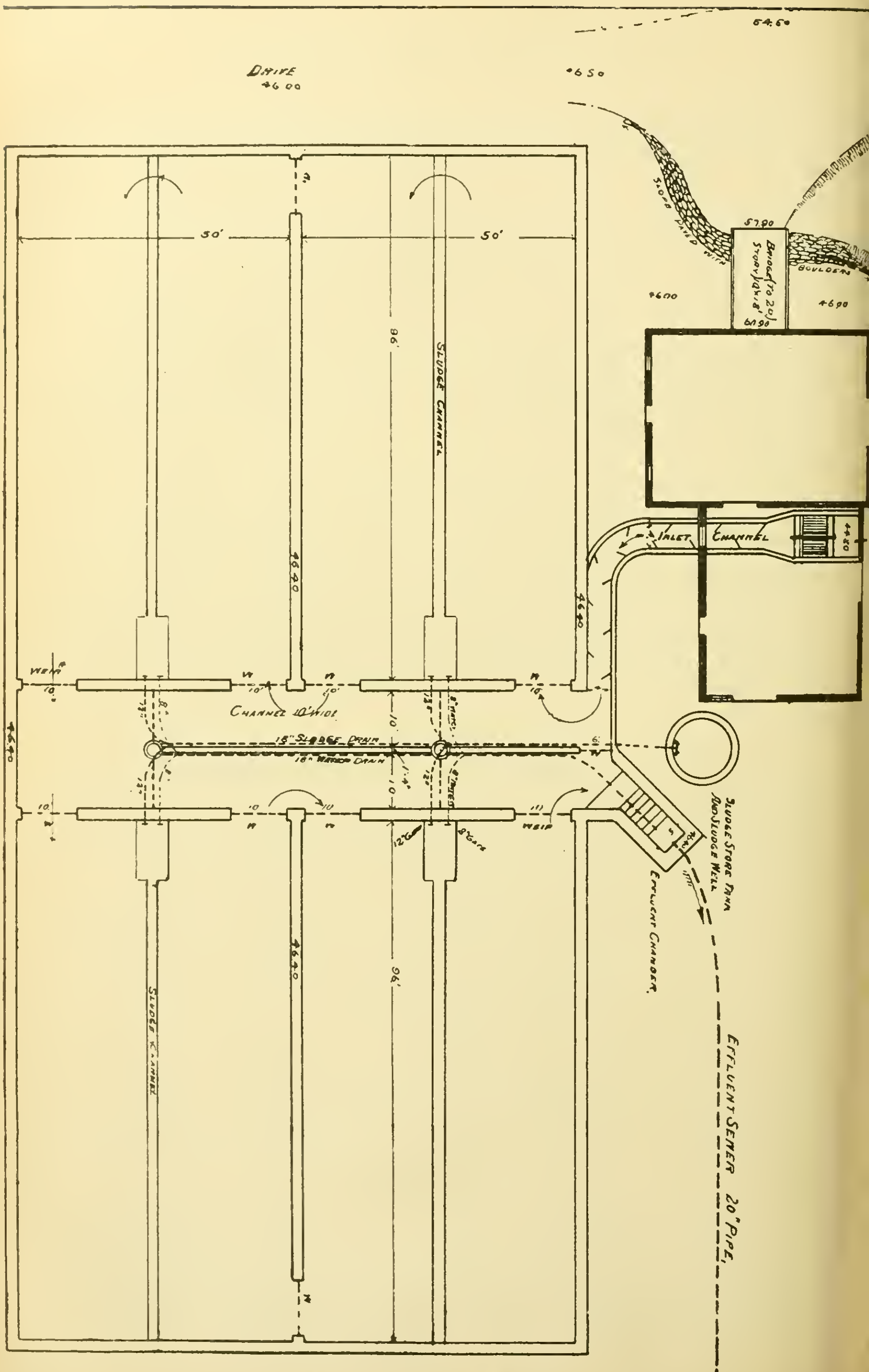
These siphons are so supplied as to flush at intervals of from eight to twenty-four hours, depending upon the number of house connections made with each individual sewer. The water discharged at each operation of the siphon varies from about 250 gallons in the 5-inch siphon to about 350 gallons in the 6-inch siphon.

In the maintenance of a sanitary system embracing some seventeen miles of sewers, no trouble has so far been experienced in keeping the entire sewer system, both laterals and mains, clean and free from any adhering organic matter or deposits by the use of this system of flushing.

SEWER DISTRICTS.

The seventeen miles of sewers are entirely in the central part of the city, known as Sewer District No. 3. To complete the plan for the entire sewering of the city involves the future construction of sanitary sewers in Sewer Districts Nos. 1 and 2. The mains from these districts are designed to discharge into the main sewer of District No. 3, at the

Fig. 1.



PLAN OF SEWAGE DISPOSAL WORKS, CANTON, OHIO.

head of what is known as the trunk sewer, and provision is thus made for the removal of all organic wastes through the trunk sewer to the City Sewer Farm located on the main branch of the Nimishilla Creek two miles south of the city and outside of the city limits.

SEWAGE FARM.

The sewer farm, embracing 28 acres of land, was originally purchased as land for the outlet, and it was intended that on this land some method of sewage purification should be perfected and carried into operation. Of these 28 acres, however, only about 13 are available for purification by land treatment, the balance being low bottom land annually flooded by the spring freshets of the stream.

METHODS OF PURIFICATION.

The subject of sewage purification was early brought to the attention of the city authorities by the complaints made by riparian owners below the outfall of the trunk sewer. An investigation of the available methods of purification developed the fact that the ground owned by the city, as well as all other land in the vicinity, was of a formation poorly adapted for purification by broad irrigation or intermittent filtration. The area of land requisite to provide for future requirements by these methods of purification could not be had except at great expense, it being then considered that for broad irrigation there would be required some 300 acres of land, the first cost of which, including the preparation of 120 acres to adapt it for the purpose, as well as the expense of a pumping plant, buildings and force main, would result in a total expense of $155,123, from which the annual expense was estimated as follows:

Interest on $155,123 at 4 per cent.	$6,244 96
Cost of pumping, per annum	1,942 40
Total expense per annum	$8,187.36

For intermittent filtration there would be required at least 50 acres of land, the preparation of 13 acres for present requirements by sloping and underdraining, a pumping plant and buildings, and a force main for lifting the sewage. The estimated total cost of all this was $45,482, and the annual expense, including interest and cost of pumping and operation, $3,861.30.

CHEMICAL PRECIPITATION.

The tract owned was, however, so located that the sewage could be brought to it by gravity, and the expense of pumping was thus obviated. Inasmuch as a large area of land would be required for broad irrigation, and as it was almost impossible to obtain for intermittent

FIG. 2. SEWAGE DISPOSAL WORKS AT CANTON OHIO.

filtration a suitable tract of ground within reasonable distance, it was deemed best to adopt the method of chemical purification for the Canton city sewage, the works to be built on the city sewage farm and the sewage brought to it by gravity.

For the purpose of arriving at the probable cost of such works, a plan, report and estimate of cost were had from Samuel M. Gray, of Providence, Rhode Island. The estimated cost of the works complete was about $38,000.

Before proceeding with the construction of the works a special committee of the city council was appointed to visit towns in the Eastern States where purification works had been constructed, and report the result of their investigation to the council for further consideration.

This committee visited the several prominent purification plants then in operation in Massachusetts, New York and New Jersey, and reported favorably upon the method of chemical precipitation recommended by Mr. Gray as being the best and most practicable, and recommended that immediate steps be taken to carry out his plans.

The committee, convinced of the ultimate success of the works, and believing that the effluent reaching the creek would be in no manner objectionable to the owners and residents of the lower creek valley, suggested certain modifications in the design of the works. Upon the adoption of this report the Board of Sewer Commissioners instructed the City Engineer to prepare an amended plan for chemical purification works in accordance with the ideas suggested by the visits of the special committee in the East; and, after several plans had been prepared and carefully studied, a plan of precipitation works somewhat similar to that built by the city of Worchester, Mass., was adopted, specifications prepared and proposals ordered.

For funds to carry on the work the city of Canton had authority, previously conferred by Act of the State Legislature, to issue $25,000 of sewage-disposal bonds; and within this amount it was deemed advisable to limit, so far as could be, the cost of the works complete and in working order.

Specifications were prepared and bids received, and contracts were awarded separately for the grading, for the construction of the inlet sewer, masonry, precipitation tanks and effluent sewer, for the building, and for the machinery and appurtenances.

COMMENCEMENT OF WORK.

Ground was broken in July, 1892, and the greater part of the brick masonry and connecting sewers was built during the same fall and the early winter. The building was erected during the winter, and the machinery and appurtenances in the spring. The entire plant was in running order by May 15, 1893, and the total cost was $26,483.76.

Fig. 3. SEWAGE DISPOSAL WORKS AT CANTON, OHIO.

THE PLANT.

The plant is contained in a heavy frame building on a brick foundation, and comprises a boiler and pump room, 28 by 30 feet, lined with brick; a chemical mixing and press room, 30 by 40 feet; and a chemical store and slaking room, 30 by 40 feet, located above the mixing room.

The four precipitating tanks are each 50 by 96 feet in plan. When filled they have an average depth of 4.75 feet; the sewage being 3 feet, 10 inches deep in the shallowest, and 5 feet, 9 inches in the deepest parts. The capacity of each tank is 171,100 gallons.

The sludge is lifted by a horizontal duplex "Voisard" sludge pump having steam cylinders 7½ inches in diameter, with 5-inch plungers and 10-inch stroke. The suction pipe connections are so arranged as to take either sludge from the sludge cistern or clear water from the clear-water well, and the discharge connections are such that the sludge may be forced into the filter press or through a line of 2½-inch pipe, outside of the building, to a sludge gravel bed, or clear water pumped from the clear-water well to an overhead storage tank within the building.

The feed pump is a duplex, 4½ by 3 by 5, so arranged that it can be used either for boiler feeding, for filling the overhead supply tank, or for pumping water under pressure for cleansing purposes about the building, and for washing down the sides of the tanks after the sludge is removed.

Steam is generated in a horizontal tubular boiler, 54 inches in diameter, and 12 feet long, placed in a substantial brick setting with full arch front. The smoke-stack is of plate-iron and 53 feet in height.

The chemical mixers are of wood and elliptical in form, with diameters of 5 and 9 feet, and 7 feet high. They are operated by an automatic vertical engine.

The filter press, Fig. 4, is a sixty-section chamber "Bonnot" press, each chamber being 29 inches in diameter and equipped with rubber gaskets to obviate the tearing of the filter cloths. The press has a traveling head with a hand-tightening gear and quick opening arrangement, with the necessary relief valves, blow-off connections and air chamber.

Within the sludge cistern is located a No. 5 pulsometer pump, the connections of which are so arranged that it can be operated from the boiler room, lifting the sludge from the cistern and discharging it either into an open tank located outside of the pumping room, or through a line of 2½ inch pipe onto a sludge gravel bed. This pump is designed to be used as an auxiliary for lifting the sludge at times when the sludge forcing pump is in need of repairs.

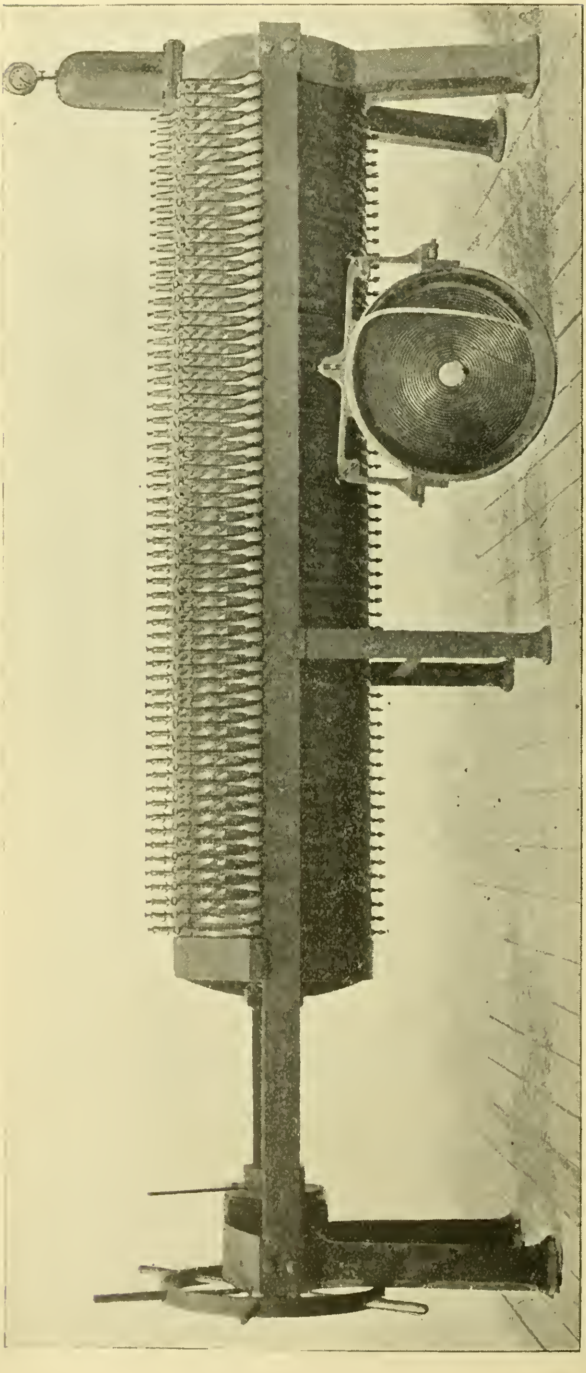


Fig. 4. BONNOT FILTER PRESS.

In case the suction lift without foot valve should at any time prove hard to maintain, the sludge can be supplied by gravity from the open tank to the suction chambers of the sludge forcing pump.

Water for all steam and mixing purposes is drawn from the effluent channel, and is pumped into an overhead storage tank holding 2,200 gallons. From this tank it is drawn off as required.

TREATMENT.

The sewage is diverted from the main sewer into the inlet sewer at a manhole, Figs. 5 and 6, just above the city farm. The inlet sewer enters the building at one end under the boiler room floor, and there enlarges into a screening chamber provided with gates and screens for the removal of obstructive matters. Thence it passes through an inlet channel 4 feet in width to the four tanks located outside of the building.

The lower end of this inlet channel connects with a double circulating channel located midway between the four precipitating tanks; two of which are placed on each side of the channel.

At the point where the sewage enters the building it receives a charge of milk of lime from the lime mixer, and where it leaves the building a solution of sulphate of alumina is added. The sewage, then passing down the inlet channel, is agitated by baffle-boards within the channel. This insures a thorough mixture of the precipitating agents with the crude sewage before the latter enters the precipitating tanks. On reaching the precipitating tanks, the sewage so charged enters the first tank and passes through it to the further end. It is then deflected back and re-enters the circulating channel, from which it enters the second tank. Thence, by the same method of circulation, it passes into and through the third and fourth tanks to its exit over the aerating steps of the effluent chamber; and thence into and through the effluent sewer to the point of outfall in the Nimishilla Creek.

The chemicals used, lime and sulphate of alumina, are delivered by wagon into the second story of the mixing room, and are there stored in their respective bins. The proper charges of lime are weighed out at regular intervals into a slaking tank located on this floor, and, after being slaked with a large surplus of water, are passed down into the lime mixer on the first floor; while the sulphate of alumina, weighed out in the requisite amounts, is dumped directly into the top of the chemical mixer, which is also on the first floor. Sufficient water is added to both the lime and alumina solution to facilitate their easy and uniform discharge into the crude sewage.

These lime and chemical mixers, as already stated, are elliptical in plan, having diameters of 5 and 9 feet, and 7 feet in height. Each mixer has two vertical shafts carrying beater arms and revolving at the

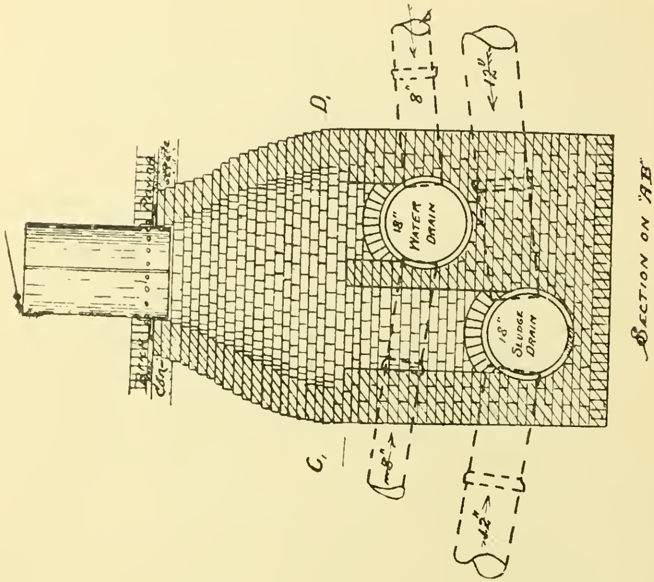

D
C
18"
WATER
DRAIN
18"
SLUDGE
DRAIN
8"
12"
SECTION ON "AB"

FIG. 6.

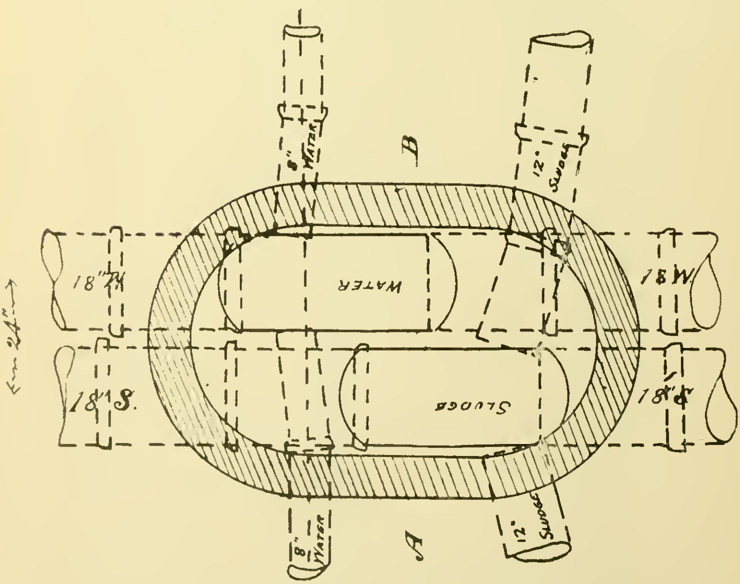

WATER
SLUDGE
8"
WATER
12"
SLUDGE
A
B
24"

FIG. 5.

rate of about twenty revolutions per minute, for the purpose of maintaining a homogeneous mixture. The agitating power is obtained from a 16 horse-power vertical engine, which drives the mixers by belting. From these mixers the solutions are discharged through 2-inch pipes controlled by gate valves so that the quantities discharged are easily regulated.

The precipitation process is such that approximately one-half of the suspended matter taken out, is deposited in the first tank and about one-fourth in the second tank, while the balance is equally distributed between the third and fourth tanks. The sludge is removed three times a week from tank No. 1; twice a week from tank No. 2; every five days from tank No. 3; and once a week from tank No. 4. This method of sludge removal gives, as shown by experiment, a uniform daily amount of sludge for pressing, and the best results in precipitation.

To remove the sludge from the bottom of each tank, the tank to be cleansed is cut out from circulation, the sewage then passing by it and into the other three tanks in rotation. After standing for some two hours, the supernatant water from the tank so cut out is decanted by means of a floating skimmer-pipe into a clear-water sewer lying beneath the circulating channel and discharging under the lower steps of the effluent chamber, and thence passes into the effluent sewer.

When the floating skimmer-pipe reaches the accumulated sludge in the bottom, the sludge is raised to the surface. Then, by means of a 12-inch gate valve, the accumulated sludge is drawn off into a sludge-sewer located under the circulating channel and discharging into a sludge-cistern placed beyond the tanks and just outside of the pumping room.

From this cistern the sludge is lifted by the suction of a duplex plunger pump with ball valves, and is forced into a sectional filter press under a pressure of about 100 pounds per square inch. From this press the exuded water passes out through the filter cloths and into a gutter beneath and thence through a drain to the inlet sewer, the solid matters being retained within the press in the form of cakes; and when the press is emptied the cakes fall into a car below. This car, when full, is run out of the building on a track, which passes across the tanks by a bridge to the sludge-cake dumping ground.

About 8 grains of lime and 1.6 grains of sulphate of alumina have been used per million gallons of sewage treated. Owing to the large capacity of the precipitating tanks, these proportions give a very satisfactory effluent. As the other districts come to be sewered, and the quantity of sewage to be treated increases, a larger amount of chemicals can be added, and thus an effluent can be maintained such as will satisfy all present and future requirements.

Should the creek-water be used as a public water supply, the effluent from the works can be further treated, without pumping, by intermittent filtration on the city's lands adjoining the works on the west side. The absence of any suspended matters in the present effluent would enable a comparatively large amount of effluent water per acre to be applied to the land prepared for intermittent filtration.

QUANTITY OF SLUDGE.

The total amount of sewage treated daily averages 880,000 gallons, from which are obtained, approximately, four tons of sludge cake per day.

The raw sludge, as it is drawn into the sludge-cistern, contains, approximately, 95 per cent. of water, and the cake obtained from filter pressing contains, approximately, 58 per cent. of moisture. About four presses of sludge per day are obtained, each press making sixty cakes of an average weight of 33⅓ pounds.

Thus far no attempt has been made to sell the sludge cake, but no difficulty is found in having the cake promptly removed from the dumping ground by farmers desiring it for fertilizer.

The average time consumed in running out a press of sludge cake is, approximately, two hours, which includes the filling of the press, the emptying and the locking up of the press ready for refilling; but the operation has been performed in 55 minutes. The rapidity of operating depends upon the texture of the filter cloths, a closely woven jute material of about fifteen threads to the inch being found most satisfactory, although not as durable as a canvas having forty threads to the inch, such as is used at present.

The life of canvas sacks approximates two months, or 200 presses, while the life of jute sacks runs somewhat less, depending upon the character of the sludge and largely upon the diameter of the central openings through the filter chambers, the larger openings giving less resistance to filtration and much better service.

The use of a duplex pump in filling the filter press has so far proved highly satisfactory. The pump, being equipped with ball valves of hard rubber, passes freely large amounts of thick and stringy matter without the slightest choking, and responds promptly to the varying requirements of the press for sludge.

MAINTENANCE.

The monthly expenses for maintenance are as follows:

One engineer in charge of the works	$60 00	per month.
One helper	40 00	"
One night engineer and watchman	40 00	"
Coal, 20 tons	31 00	"

Lime, 15 tons	$42 00	per month.
Sulphate of alumina, 3 tons	60 00	"
Oil and waste	8 00	"
Filter cloths	10 00	"
Miscellaneous	3 10	"
Total per month	$295 00	
	$3540	per year.

This amounts to 23.6 cents *per capita* per year with a population of 15,000 persons in the district connected with the sewers, or $11.19 per million gallons of sewage treated.

For an increase in the amount of sewage treated the cost for attendance, coal and other supplies would remain the same, and the additional cost would practically be only that of the additional lime and alumina required.

During the winter months, and at times of freshets and high water, only so much sewage will be passed through the precipitating tanks as will suffice to protect them from frost, chemical treatment will be entirely omitted, and only sufficient help will be retained at the works to properly care for them. In this manner the annual expense will be reduced to a figure materially below that named.

TEMPERATURE.

The lowest observed temperature of the sewage at the outfall in the coldest weather of the winter of 1892–93 was 46° Fahrenheit, and at the same time the city water supply was at a temperature of 34°.

The lowest temperatures observed during the recent cold weather, when the temperature of the external air was 16° Fahrenheit, was 50° for the sewage at the mouth of the inlet sewer; 48° where it enters tank No. 1; 49° at the farther end of tank No. 1; 47° in each end of tank No. 2 and in tank No. 3; 46° in tank No. 4, and 45° in the effluent water at the foot of the aerating steps, showing a total loss of temperature of 5° in the passage of the sewage through the tanks.

On the basis of the same decrease in temperature for the colder weather in the winter, when the temperature of the external air stands below zero, it is unlikely that the temperature of the effluent for continuous circulation will fall below 41° or 40° Fahrenheit.

ANALYSES.

Several analyses have been made of the sewage and of the effluent, but the conditions under which the samples were taken were such that the results obtained by the analyses thus far made do not show the true working of the plant, for the samples have been taken within too limited a period of time, and too long a time was allowed to intervene between the collection of the samples and their analysis.

Generally speaking, the analyses show that, using lime alone, and at the rate of 1,100 pounds per million gallons of sewage, 59 per cent. of the organic matter contained was removed by the process of treatment. No analysis of the effluent has been made since the use of sulphate of alumina, in addition to the lime, was adopted.

The indications, so far as one can judge from an inspection of the effluent, are that by the addition of 200 pounds of sulphate of alumina per day a much higher degree of purification is attained.

The analysis of the lime used shows the following composition:

Calcium oxide	84.7	per cent.
Magnesium oxide	1.5	"
Ferric oxide	5.8	"
Moisture, carbonic acid and undetermined	8.0	"
Total	100.0	"
Lime, soluble in water	82.5	"

This is a local lime, costing 10 cents per bushel of 70 pounds delivered in the bin at the works.

The sulphate of alumina, so far used, is represented as containing insoluble matter, 10 per cent., and sulphate of alumina, 44 per cent. It costs, in a pulverized condition, about $20 per ton in car-load lots delivered at the works.

Investigations are now in progress to determine the suitability of other grades of sulphate of alumina, with the idea of obtaining, at the lowest cost, that most suitable for the process.

The operation of the works has continued to be highly satisfactory to the citizens of Canton and to the riparian owners of the lower creek valley; and no odors of any nature are discernible at any time about the plant. The authorities are well satisfied with the results of chemical precipitation for the disposal of house sewage.

DISCUSSION.

Mr. E. P. Roberts.—I would ask whether the five cents include interest and depreciation.

Mr. L. E. Chapin.—No, sir. The interest on depreciation is five cents. That is for two million gallons per day.

Mr. Roberts.—Has there been a difficulty in getting the farmers to take away the sludge? Do they get it free, and do they take it away in sufficient quantities?

Mr. Chapin.—In the start we were compelled to haul the sludge away by our city teams about three times a week. As time went on,

parties offered to haul it away, but for a consideration. Finally an agreement was entered into with a farmer who had been one of the strongest objectors to turning the crude sewage into the stream. By this agreement he was to keep the sludge cleaned up from the works until ordered by the city to stop. This man seems to be well pleased with the arrangement, for he has several times objected to our furnishing the sludge to any one else.

Mr. Hosea Paul.—I think it is a reproach to our civilization that it has so long been the practice to befoul our streams and water courses with the contaminated matter and waste products resulting from our water supply, especially those streams and fountains from which we derive our supply of drinking water. The reproach, I think, extends to our engineering profession, for it is not beyond their power to rectify such evils, and yet, while they are the servants of the public, they permit these evils to exist. It may be said, however, that whenever the public demands something better, the engineers are ready to furnish it. Here is a case in point, where one of our progressive engineers has taken up the subject for one of our smaller cities. In this matter, as in some others, the smaller cities are in advance of the larger ones. So far as the State of Ohio is concerned, Mr. Chapin is a pioneer, but purification is in use in various cities in New England, and, I think, in one or two in New York—in Rochester, I believe.

Mr. Chapin.—Chautauqua has a precipitation plant.

Mr. Paul.—A great deal has been written on this subject in a popular way. One of the theories advanced has been that all we have to do with sewage is to spread it over our fields, whereupon it will become a fertilizer of the greatest value. It seems that this particular idea, although widely circulated, has been pretty much abandoned, and the newer methods of sewage purification have come into use. I have recently read in one of the magazines of a process by which a powerful electric current is connected with a stream or body of polluted water, and, presto! that water is converted into an innocuous and possibly palatable fluid.

Mr. Chapin.—Sometimes a method of sewage purification that is very satisfactory in one place is entirely unsuitable for another, depending largely upon the composition and the temperature of the sewage. In filtration, sewage of a low temperature is very apt to cause a nuisance in winter, when the frost is say eight inches or a foot deep, for when the sewage is turned from one bed to another over the ditches or channels, the ground refuses to soften under sewage of a low temperature and the cold water forms a pool of ice, so that little or no purification takes place. But where the temperature of the sewage is something above 40° there seems to be no trouble of this kind. Then again the uses made of

the water of streams into which sewage is turned, determine largely the degree of purification which must be accomplished. I doubt very much whether the water in Canton would be found fit for drinking. What we are now doing, and what we expect to continue doing, is to remove all of the suspended matter, and so much of the matter in solution as we can, and to satisfy the people in the lower Creek Valley.

With 8 grains of lime and 1.6 grains of sulphate of alumina per gallon, we are able to turn the effluent into the stream nearly as clear as the glass of water on the table, while the sewage is very foul as it enters the works. But considerable organic matter still remains in solution in the effluent. I know of no case where more than 80 per cent. of organic matter has been removed from an effluent by precipitation. In broad irrigation, when the sewage is turned over the surface of the ground, it may at one place be a few inches in depth, and from that run out to nothing, so that a large amount of organic matter accumulates and decomposes at the point of discharge. This requires careful attention in the management in order to avoid nuisance. For intermittent filtration the channels should be so arranged that no sewage is left to decompose when the channel is not in use. So far as the application of electricity is concerned, I have as yet seen nothing that will show the practical working of such a system, or its cost in dollars and cents, which is what interests most of us.

Mr. Roberts.—The electrical method, as used in England, consists in passing the fluid between iron plates, one positive and the other negative. By this method the gases are liberated with much stronger deoxidizing powers than when they are liberated out of contact with the material to be acted upon. Of two plants that have been operated for several years in England, the estimated cost of one is, I believe, 30 cents per million gallons, including interest and depreciation, which are, I believe, included also in the figures quoted for Canton. Cast-iron is one of the principal items, and is charged at $20 per ton. It is claimed, however, that this method gives a better effluent than the mechanical method.

Mr. C. M. Barber.—I think the electrical method has a possible advantage in that it separates not only the matter that is in suspension, but some of that which is in chemical combination, such as lime and some other substances. Possibly it might be a good method for removing lime, etc., from feed water for steam boilers.

Mr. Wm. H. Searles.—I wish to express my admiration for the very clear and satisfactory manner in which this subject has been presented to the club by Mr. Chapin. It is a practical paper, on a practical subject, and has been presented with all its practical details, so that we have a clear understanding of the problem which has been worked out at Canton.

This is a problem which is coming to the front in a great many of our cities. Sewage purification is a step in the progress of modern civilization. First, a town must have water. It seeks sources of supply and methods of distribution. No sooner are these obtained than the necessity for sewers arises; and perhaps in the first instance a crude method of sewerage answers the purpose. As population increases, and with it the amount of water used, we discover that the sewage becomes a nuisance, either to the people in the town or to those down stream from it. Then comes the necessity for purification works and for doing away with the defilement of our streams, and with the injury to the face of nature generally. As has been remarked, the form of purification for each case must be judiciously selected according to the circumstances. The method pursued at Canton is simple and inexpensive, and the results are satisfactory to the parties interested. While the effluent may not be so pure as might be desired, or as may hereafter be demanded, the construction of the works is nevertheless a step in the right direction, and creditable to the designers and builders.

There are but few towns so situated that effluent sewage can safely be turned adrift to take care of itself. Cleveland perhaps is very fortunately situated in that respect. Yet the time may come when even Cleveland will be compelled to do something in this direction. Many inland towns on small streams, or where there is no stream of any consequence, will certainly be compelled, if they use a general water supply, to provide themselves also with works for the purification of sewage.

Mr. Chapin.—Mr. Paul has suggested the desirability of naming the size of the stream into which our effluent passes. To-day there are probably 30,000,000 gallons of water flowing. This summer and fall for something like ninety days, the flow did not exceed 4,000,000 gallons per day, and for over sixty days the flow was but little more than that of the water from the sewer itself. The waters in the main stream, such as they are in this dry weather, pass through a mill-race, and are re-discharged into the bed of the stream about three-quarters of a mile below. So that there is a part of the stream, about a mile long, in which, practically, the only water flowing has been that from the works. The volume of the stream, from now until March, will probably average fifty or sixty million gallons a day, and during this period we intend to use but a small quantity of chemicals, depending entirely upon the volume of water in the stream. Had we been in possession of the necessary funds, we should have used regularly the requisite amount of sulphate of alumina, and we should then have been able to present to the society some creditable analyses of the effluent.

Mr. H. B. Strong.—What is the velocity of the flow through the four tanks?

Mr. Chapin.—It takes about twenty hours for the sewage to pass through the tanks. The velocity is not noticeable, except as it passes through the shallow circulating channels into the tanks.

Mr. Barber.—I would ask whether the principle of aeration is used to any great extent in sewage purification?

Mr. Chapin.—The effluent from nearly all chemical precipitation plants is aerated; for the chemical processes rob the effluent of a large proportion of its oxygen, and if it is then turned into streams of small size it is detrimental to fish life. Hence aeration is employed for the purpose of restoring the oxygen.

Mr. Barber.—Do you not use aeration, by forcing air into the water, for the purpose of precipitating the organic matter?

Mr. Chapin.—No, sir. I understand that aeration is practised in the public water supply of some Eastern cities; but my impression is that the main object of this is to remove the foul odor of the water.

The Chair.—We have lately received from the State Board of Health of Massachusetts its last report, and it is now in our library. In it you will find an elaborate discussion of sewage purification as practised in a number of the small cities of Massachusetts, especially those around Boston. The Boston water supply is taken from streams which pass near some of these places, and hence it became absolutely necessary to have all water or sewage purified before it was admitted into any of these streams. The city of Boston, in many cases, helps to pay a portion of the expenses. I think that in some places as much as 90 to 92 per cent. of the organic matter held in solution has been removed. Before Mr. Chapin began operations at Canton he investigated a variety of methods used in the East. Intermittent filtration is in some places considered objectionable, but in most cases it works fairly well. In other cases chemical precipitation is employed, and in many such cases over 90 per cent. of the matter held in solution has, I believe, been removed. Some of you may have visited the sewage purification works at the World's Fair, which, I think, were quite different from those at Canton. I do not remember now what amount was disposed of. The sludge, after being pressed, was passed through a crematory and consumed. The workmen told me that lime was the only chemical precipitant used there. The lime was placed in large cylindrical tanks having conical bottoms and allowed to stand for several hours. The sludge settled to the bottom, the clear water was drawn off, and the sludge was then pressed and burned. Three systems of drainage were in use there, I believe. One was for removing the storm water from the buildings; another was for removing the surface water and drainage, and the third was the Shone system for sewage. The sewage was the only product taken to the sewage works, the storm and surface

water being emptied directly into the lake. The effluent from the purification works in Massachusetts was so clear that it was allowed to run back into the streams, and, of course, was very much diluted. It finally found its way into the drinking waters of Boston. In the Massachusetts report was one matter which is in line with what Mr. Paul mentioned about the pollution of streams. The law, I think, does not prevent such pollution, but prevents cities from taking their water supplies from streams within twenty miles of the points where they are polluted. Some very serious epidemics have broken out where drinking water was taken from polluted streams, even though the sewage was very extensively diluted. It is astonishing how such poisonous matter can be carried in suspension and remain alive and ready for work when taken into the human system, although in very minute quantities. Even when water is as nearly purified as that of the Stony Brook at Lowell, Mass., where it empties into the Merrimac River, it is a great source of danger. The Stony Brook water caused the epidemics at Lowell in 1890 and 1891, and, after leaving Lowell, it caused another in Lawrence, a number of miles below. This is not a rapid stream, but it is rapid enough to take the poisonous matter along with it. So far as I know, Canton is the only town in Ohio provided with works for the purification of sewage; but many others must need it now or in the near future.

JOSEPH COULSON.

A MEMOIR.

By R. A. Hale and F. S. Hart, Committee of the Boston Society of Civil Engineers.

[Read January 24, 1894.]

Joseph Coulson, Jr., was born in Lowell, Mass., November 13, 1861. At an early age he removed with his parents from Lowell to California. In 1870 he returned with his parents to the East and settled in Lawrence, Mass., where he first attended St. Mary's School and afterwards the public schools. He graduated with honors from the High School in the class of 1882. He then entered the employ of the Proprietors of the Locks and Canals at Lowell, on August 11, 1882, being engaged as observer and computer on water measurements and in general office matters. There he engaged heartily in the work and was always found faithful and diligent, thoroughly conscientious in the discharge of all his duties, upright and noble in his character. He strove constantly to acquire further knowledge in the line of his vocation, yet the drudgery of routine work called forth but little complaint from him. He left Lowell September 24, 1885, to commence the school year at the Massachusetts Institute of Technology, and returned to Lowell June 1, 1886, for summer work with the Locks and Canals Company. He again left their employ September 24, 1886, to enter upon his second year at the Institute. On the completion of his school year, July 26, 1887, he entered the City Engineer's Department in Boston, where he remained until October 27, 1888. During this period his special work was on the Back Bay Fens, the iron pier at Marine Park, and other work connected with the Department of Parks. He was in charge of a party during a portion of the time and was also engaged in drafting in the office. He was quick and accurate and took an active interest in all matters pertaining to his work.

In November, 1888, he went South to accept a position in the United States Engineering Department in the Savannah District, under charge of Capt. Carter, U. S. A., and was assigned to duty at Brunswick, Georgia. He was employed as surveyor and inspector at various places in the Savannah District until July, 1891, when he was promoted to Assistant Engineer and placed in local charge of the works of improvement at Cumberland Sound, Georgia and Florida, with station at Fernandina, Florida. In August, 1892, for his faithful and efficient services he was promoted to be the principal assistant engineer for the entire Savannah District, with his headquarters at Savannah, Georgia.

In addition to his skill as a civil engineer, Mr. Coulson was an expert photographer, and the exhibit of the various Government works in the Savannah District prepared for the World's Columbian Exposition was based in the main upon photographs taken by him.

On July 8, 1891, Mr. Coulson married Miss Eliza Tavel, of Fernandina, Florida, and two children were the result of their union. The youngest died some months ago, and the remaining child, a boy, survives.

Mr. Coulson died at Savannah, Sunday, January 22, 1893, of malignant scarlet fever, after an illness of five days. His wife was also stricken with the same disease, but she has since recovered. In his private life Mr. Coulson was devotedly attached to his family, and his death was a severe blow to them. In a letter recently received, Capt. Carter, U. S. A., states that "during Mr. Coulson's service here I always found him to be a man not only of ability, but of high character and worthy of being intrusted with the execution of works of great importance."

In his duties in the City Engineer's Department in Boston, and at Lowell, his faithfulness, his application to the work in hand, and the courtesy with which his associates were treated, have made a lasting impression upon all who came in contact with him. He joined the Boston Society of Civil Engineers January 18, 1888. Owing to his subsequent removal from the city he was not able to attend the meetings, and consequently had but a limited acquaintance with his fellow-engineers, but the loss of a member of such integrity and standing cannot but be severely felt by the Society.

RICHARD FOBES.

A MEMOIR.

By L. A. Taylor and C. A. Allen, Committee of the Boston Society of Civil Engineers.

[Read December 20, 1893.]

Richard Fobes was born September 8, 1858, in Lebanon, Maine. His father is the Rev. W. A. Fobes, of Worcester, Mass. From Lebanon the family moved to Halifax, and afterward to Chesterfield and Monterey, Mass. It was in these towns that Richard Fobes attended the public schools, and while the educational advantages there afforded were somewhat limited, he acquired by his industry an unusually good education.

Late in the year 1877 he entered the office of Charles A. Allen, civil engineer, of Worcester, and upon Mr. Allen's election as City Engineer in January, 1878, he entered the employ of the city as Assistant Engineer of the Sewer Department.

During 1878, '79 and '80 he had charge to a very great extent of important sewer construction, and it was at this time that his unusual executive ability manifested itself. He now made rapid strides in his profession. In 1881 he left the employ of the city and was engaged as an engineer on the Connotton Valley Railroad at Cleveland, O., where he was placed in charge of a portion of the work connected with the terminal facilities and with the construction of the bridge that spanned the river. In 1882 he was in the employ of John W. Ellis, civil engineer, of Woonsocket, R. I., where he had charge of the construction of the Millford, Franklin and Providence Railroad, from Franklin to Bellingham.

Early in 1883 he returned to the city engineer's office at Worcester and was placed in charge of the Sewer Department as assistant engineer. He held this position until April, 1889, when, upon the resignation of Gen. Chamberlain, Superintendent of Sewers, Mr. Fobes was elected in his place. He held this office until the time of his death, being unanimously re-elected annually.

Some of the most important work done by the city of Worcester in connection with its sewerage system was executed by Mr. Fobes during his term of office as Superintendent of Sewers, and it can be said to his credit that in every particular the work was carried to completion in a most thorough and satisfactory manner. He frequently received the compliments of his superior officers for the thoroughness and fidelity which he displayed.

His administration of the office stands as one of the most successful in the history of the Sewer Department in the city of Worcester. All of the work was done by day labor, so that the entire responsibility of employing the men, and of so arranging matters as to do the work economically, rested upon his shoulders.

Among the important matters that he carried through successfully were the construction of two tunnels through rock and gravel. These convey the sewage from the western part of the city into the general sewerage system, so that all the sewage of the city is concentrated at one point for treatment before being emptied into the Blackstone River. Up to the time of his death Mr. Fobes had charge, as executive officer, of the construction of the sewage purification works, and a very large share of the credit for the successful operation of this important plant is due to his untiring labor.

Mr. Fobes enjoyed the universal respect of the employees in his department, as well as of those with whom he was connected officially.

After an illness of a few days he died of pneumonia, February 5, 1891. He was unmarried.

He became a member of this Society June 20, 1888, and was much interested in its welfare.

THE CONTRIBUTION BOX.

Members of the associated societies, and other persons, are invited to send to the Secretary, for this department of the JOURNAL, such matters of general interest as may come to their notice.

The New Quarters of the Engineers' Club of St. Louis.

After trying various experiments in the matter of renting rooms for its use, the Engineers' Club has finally joined hands with the St. Louis Academy of Sciences and the Missouri Historical Society in leasing a large double residence in the central part of the city, on a retired street, but convenient of access, and the members are very much pleased with the result. There is one common meeting room, seating about 100 persons and suitably arranged for stereopticon exhibitions. The remaining portion of the building is given up to office, library and museum purposes. Each society has its own private office, library and reading rooms. A secretary and a janitor are employed jointly by the three societies, the secretary acting also as librarian for all the societies. Notices of meetings for all the societies are sent out by him, and although each society has its own recording secretary, yet the joint secretary does so large a part of the manual work of a secretary's position, that a considerable amount of expense is saved in this way. It is hoped that before many years a building will be erected, specially designed to accommodate these joint interests, in which case other societies of a similar character might also be included. The building is open at all hours of the day, and by pass-key at night, when the janitor only is in charge. By a union of interests of this kind much better service is obtained for all the societies, without any inconvenience, and at a very much less cost than would otherwise be possible. Would not such an arrangement be practicable in most cities for the accommodation of engineering societies?

As She is Printed.

That the Philadelphia Traction Company is master not only of the fates and destinies of the citizens of Philadelphia, but also of the English language, is manifest from this gem, taken from a transfer ticket issued on its Spruce and Pine Streets Division :

"This Transfer Ticket is given only to passengers entering car on Pine Street, and asks for and receives same at time of payment of Cash Fare. Otherwise the Conductor is not permitted to give it."

Propositions for New National and International Engineering Societies.

At the Annual Meeting of the Western Society of Engineers, held January 3d, the newly elected President, Mr. Hiero B. Herr, addressed the members present

in favor of the formation of a new national engineering society, to have its headquarters in Chicago, and to have a name signifying its national character, such as The American Society of Engineers, or The Engineering Institution of the United States, or The United States Institute of Engineering.

He argued that the term "Western," as applied to a society with headquarters in Chicago, was a misnomer, and that Chicago, by virtue of its central position, and of having demonstrated the justness of its claim to be considered the metropolis of America, was *par excellence* the city where this great national society should have its home.

At the February meeting of the Society, the proceedings of which are printed in this issue of the JOURNAL, Mr. E. L. Corthell presented a communication suggesting the formation of an International Institute of Engineers, and a communication was read from Mr. Charles Hansel proposing the formation of a local club, to be called the Chicago Construction Club.

These three propositions, submitted almost simultaneously before one and the same Society, while they are radically different in their aims and scopes and in the results which must follow from their effectual carrying out, are, nevertheless, alike in this, that they evidence a remarkable tendency which may or may not be merely local and consequent upon the successful issue of the World's Fair of a tendency to crystallization, to the formation of new and more powerful organizations.

Mr. Hansel's proposition concerns chiefly those engineers who reside in and near Chicago; but the other two, as will be seen at a glance, are far-reaching in their aims, and the consummation of either or both of them would profoundly affect existing organizations of engineers.

The whole subject was referred by the Western Society to a committee of seven; but the ideas involved are of great moment, not only to the members of the society where they were brought forward, but to all the engineers of this country, while Mr. Corthell's suggestion comes home to every engineer in the world.

It therefore strikes the Box as eminently fitting that the attention of the readers of the JOURNAL should be called to these matters, and that they should be fully discussed in these columns.

A Method of Dealing with a High Dam Subject to Unequal Settlement.

Probably the most notable group of high dams in the world is to be found on the Croton water-shed, where New York City now has under contract some five earthen or masonry dams of more or less extraordinary proportions. Among them is the "New Croton" dam, which is to be 65 feet higher than any dam yet constructed. Its originality of design, not less than these unprecedented proportions, will make its designer, Mr. Alphonse Fteley, deservedly famous. A very common feature of the rock formation throughout the Croton Valley is the presence of bold outcroppings on one side of the valley, and their total disappearance on the other side, upon which the rock dips so far underground as to be practically beyond reach for foundations. These conditions were found to obtain at the site for the "Titicus" dam, near Purdy Station, New York, and led to the introduction of a novel and perhaps noteworthy feature in construction. The dam is 135 feet high and 1,500 feet long. About 500 feet of the length of the dam, under which the foundation is of rock, is entirely of masonry, while the remaining portion is of earth with a

masonry core-wall. At the point where the rock foundation ceases and the clay foundation begins, the core-wall is about 130 feet high. The transition from rock to clay, with its tendency to produce a crack by unequal settlement, thus becomes a very serious matter. Similar conditions at "Sodom" dam having caused the wall to crack, Mr. Fteley anticipated such action at "Titicus" dam, by leaving a large well-hole running from the bottom to the top of the wall, at the point where the foundation changes from rock to clay. The purpose of the well-hole was to so weaken the wall that it would be sure to crack at this point, if anywhere, and after the completion of the work, when settlement had ceased, the well-hole was to be filled with concrete, thus effectually stopping any leakage. As a matter of fact, when the wall had reached a height of 50 feet, a crack appeared, as anticipated, on each side of the well-hole. The concrete filling when in place, however, will re-establish the integrity of the wall and prevent any leakage.

English Trade vs. English Weights and Measures.

Mr. Edward Johnson, of Botolph House, Eastcheap, London, Secretary of the New Decimal Association, has issued a circular setting forth the fact that British trade in certain quarters of the globe is suffering in consequence of British adherence to British weights and measures.

For instance, Mr. Johnson tells us that in the last published Foreign Office Report (No. 1300) on the trade, etc., of Bulgaria, it is stated that would-be sellers in England do sometimes go so far as to send out catalogues in French or some other foreign language, but that even then they "persist in retaining the intricate English standards of weights and measures." It is added: "The Metric System is the one now employed throughout Bulgaria, and it is useless for English manufacturers, especially of machinery and hardware, to expect that their potential foreign customers will give themselves the trouble of learning our avoirdupois and dimension tables, in order to be able to puzzle out quarters, pounds and ounces, yards and inches, gallons, pints, etc., into their metric equivalents."

Regarding Peru, a correspondent writes complaining of the inconvenience he suffers when consigning machinery. The shipping specifications have to be sent out in metric weights and measures, and if there are any errors his customers are liable to a fine. This means he has to make out the specifications twice over, first in English and then in metric weights and measures. He, therefore, and not unreasonably, urges that the metric system should be officially adopted in England.

THE LIBRARY.

It is proposed to notice briefly in this department of the JOURNAL such engineering publications as may find their way to our shelves.

Publishers are requested, in sending works for review, to state the prices of same.

Modern Framed Structures, THE THEORY AND PRACTICE OF—. By J. B. Johnson, C. E., Professor of Civil Engineering in Washington University, St. Louis, Mo.; C. W. Bryan, C. E., Engineer of the Edge Moor Bridge Works, Wilmington, Del.; and F. E. Turneaure, C. E., Professor of Bridge and Hydraulic Engineering, University of Wisconsin, Madison. Second edition, revised. New York: John Wiley & Sons. 1894. 517 pages, 8 x by 10½ inches. Well and thoroughly illustrated. Index. $10.00.

It is gratifying to see this truly standard work already in its second edition. As might have been expected, this edition differs but little from its predecessor, for even in these days of rapid progress no very radical changes in theory or in practice could have taken place within the short time that has elapsed since the appearance of the first edition. The book is unique in the matter of its illustrations, which have been prepared with most commendable care. A feature peculiar to this work is Chapter 26, dealing with the æsthetic design of bridges and illustrated by means of numerous foreign and domestic examples. The chapter devoted to the consideration of standpipes and elevated tanks is particularly timely in these days of numerous failures of such structures. Another chapter, rather unfortunately named, is devoted to Iron and Steel Tall Building Construction.

Appendix A is an adaptation of a paper on the use of soft steel in bridges, read by Mr. F. H. Lewis before the Engineers' Club of Philadelphia. Appendix B treats of the processes in the manufacture and construction of iron and steel buildings. Appendix C, on American methods of bridge erection, is adapted from a lecture by Frank W. Skinner before the Club of Civil Engineers of Cornell University in April, 1893.

Manuale dell'Ingegnere Civile e Industriale. Per G. Colombo, Engineer, Professor of Mechanics and Machine Construction in the Royal Technical Institute of Milan. Thirteenth edition. Ulrico Hoepli, Milan, 1893. 356 pages, 4 x 6 inches, of small type. 203 cuts. Lira, 5.50 (= $1.10).

This little work, the first edition of which appeared in 1877, comes to us from a valued Italian correspondent, who speaks in glowing terms of the high estimation in which it is held by his compatriots. It is to them in short what the "Taschenbuch Hütte" is to the Germans. The author states in the Preface of the first edition that the work is not a mere compilation or an imitation of foreign manuals, but is derived largely from his own experience. The present thirteenth edition is modified and enlarged, especially in the departments of Mathematics, Hydraulics and Mechanics.

Electricity is briefly disposed of in five pages, while 26 are devoted to Hydraulics and 4 to Hydraulic Construction. Three pages are given to Agriculture and 13 to Strength of Materials, 40 to Transmission of Power, 14 to Water Wheels and Turbines, 33 to Steam Engines, 7 to Steam Navigation and 9 to Gas and Hot Air Engines. The remarks upon Railroads are of course based upon foreign practice.

This work, like the "Hütte," contains brief sketches of the important features of various technical pursuits, such as paper making, the manufacture of cloth, etc., devoting 28 pages to such matter. Thirty-one pages are devoted to matters of administration, including laws governing building construction.

Like some of our own pocket-books this manual has found place between its boards for advertisements, and indeed to an extent which none of our American pocket-books approach to, 48 pages at the back being taken up with the catalogue of the publisher.

Tidal Rivers: Their (1) Hydraulics, (2) Improvement, (3) Navigation. By W. H. Wheeler, M. Inst. C. E. London: Longmans, Green & Co., and New York: 15 E. Sixteenth Street. 1893. 455 pages, $4\frac{1}{2}$ x $9\frac{1}{2}$ inches. Index. Illustrated.

This work, as is usual and perhaps proper in such treatises, opens with an historical review of the subject. Then follow chapters on the motion of the water in tidal rivers and its transporting power. Chapter V is devoted to the tides, and gives data respecting the rates of propagation of the tidal wave in the Seine and in British rivers. Under the head of "Training and Dredging," a description is given of the Lobnitz Dérocheuse, as used in the Suez Canal. Short chapters are devoted to buoying and lighting and to the surveying of tidal rivers. Among the examples of important tidal rivers, the Clyde, of course, occupies a prominent position, as do also the Mersey, with its exceptionally high range of tide, in connection with which the Manchester Ship Canal is described, and the River Dee. To our surprise, we find no reference to the world-renowned Bore of the last-named river. In treating of the Clyde, the author quotes Telford as remarking, in 1817, that at that time the Clyde had not been rendered as perfect as the Dee.

Appendix II gives a glossary of French and English terms relating to tidal rivers. That the work is not very intensely mathematical, may be seen from Appendix V, giving the notation used in the work and containing only ten items. The author uses English measures throughout, and gives, as his formula for velocity:

$$V = C \sqrt{2 R F},$$

where

V = velocity in feet per second,

C = a coefficient varying, with the volume of discharge, from 0.65 to 1.50.

R = hydraulic mean radius,

F = slope in feet per mile.

In tidal rivers $C = 0.85$ to 1.50. When discharge = 100,000 cubic feet per second, $C = 1$.

The author holds that "the engineer requires a formula having as few figures as possible."

Waterworks Engineering, The Principles of—. By J. H. Tudsbery Turner, B. Sc., M. Inst. C. E.; and A. W. Brightmore, M. Sc. Assoc., Mem. Inst. C. E. London: E. & F. N. Spon. New York: Spon & Chamberlain, 12 Cortlandt Street. 1893. 420 pages, $4\frac{1}{2}$ x 9 inches. Handsomely printed on good paper in large type. Index. Illustrated. Price, 25 shillings ($6.25).

The author evidently means to cover very much the same ground as is covered by Mr. Fanning's American work upon the same subject. The sources of water

supply and the impurities to which it is liable are considered in detail. Under Measurement of Water the author proceeds to consider the subjects of Rainfall, Gages, Theories of Flow and various Methods of Measurement, including the weir; in which Mr. Francis' experiments and those of Fteley and Stearns are noticed ; Current Meters, including those of Pitot and Darcy ; and Water Meters, including the Venturi.

The chapter on pumps seems rather incomplete and bare of illustrations for a work of this kind. Considerable attention has been paid to ancient devices, such as Archimedes' screw, the chain pump and the hydraulic ram, but comparatively little to pumps of modern form.

Chapter 4, which treats of the Storage of Water, illustrates earthen embankments and masonry dams in considerable detail, and elaborates the theory of the latter. Chapter 5 deals with the purification of water, and, as is natural in an English work, has much to say about filters. Porter's filter press is illustrated, and in this connection we might refer to the Bonnot press at Canton, Ohio, described in Mr. Chapin's paper in the present issue of the JOURNAL.

Chapter 6, on the Conveyance of Water, devotes considerable attention to the testing of pipes, to pipe laying and pouring, and to flexible and other pipe joints.

Chapters 7 and 8 deal with the Distribution of Water and the Maintenance of Waterworks.

Engineering Education. Being the proceedings of Section E of the World's Engineering Congress, held in Chicago, Ill., July 31st to August 5th, 1893. Published by the Society for the Promotion of Engineering Education as Volume I of their Proceedings. Edited by DeVolson Wood, Ira O. Baker, J. B. Johnson, Committee. Columbia, Mo.: E. W. Stephens, Printer, 1894. 342 pages, 6 x $8\frac{1}{2}$ inches. Handsomely printed on good paper and in large type.

In this era of rapid and radical change, no revolution of deeper significance has taken place than that which has, within a little more than half a century, so completely transformed the methods by which engineers are educated.

Our immediate ancestors were thankful if they could claim to have received "a common school education," and were then at once turned out to active work, often, indeed, acquiring considerable reputation at an age when our boys are only getting fairly into the hazing period.

Men that might still be called young can remember when colleges of engineering were scarcely heard of, and when it was seriously debated whether any departure from the established and largely classical curriculum was to be recommended, even for men who were to spend their lives in active business.

The present volume, containing the proceedings of a World's Congress on Engineering Education, held under the auspices of such men as E. L. Corthell, Chairman of the General Committee of the World's Congress Auxiliary on Engineering Congresses ; Prof. Ira O. Baker, Chairman of Special Committee for the Division of Engineering Education ; and Prof. De Volson Wood, President of the Society for Promoting Engineering Education, is an excellent index of the extent to which the subject of the education of the engineer is engrossing the leading minds in the profession.

In addition to the proceedings of the Congress, the volume contains papers and discussions from many of our most prominent educators of engineers. Most of these papers have already appeared in the engineering journals.

United States Coast and Geodetic Survey, Report of the Superintendent of the—. For the fiscal year ending June 30, 1891. In two parts. Washington: Government Printing Office, 1892.

With the issue of this number the experiment has been tried of issuing the Report in two parts; Part I, quarto, containing notes of the progress of the work in the past and of the anticipated progress in the future, together with maps and progress sketches, and Part II, octavo, containing professional papers relating to the methods and results of the survey. As a rule, Part II only is sent out to the public. In this departure the Survey follows the example recently set by the Chief of Engineers, U. S. A., in issuing his annual Report.

Appendix 10 describes and illustrates the use of the Direction Current Meter, devised by Messrs. E. E. Haskell and E. S. Ritchie, with observations made by means of it in the Straits of Florida and in the Gulf of Mexico. The instrument records electrically the direction and velocity of the current.

Appendix 11 contains an exceedingly valuable index of the various publications of the Survey, and is divided into eight portions, in which are grouped respectively the various classes of publications.

In Appendix 15, Supt. Mendenhall describes determinations of gravity with the new half-second pendulums at stations on the Pacific Coast, in Alaska, at Washington, D. C., and at Hoboken, N. J.

The volume concludes with Appendix 16, giving a report of the Topographical Conference at Washington, convened by direction of the Superintendent in January, 1892. Among the interesting matters presented at this conference was a review of photographic surveys conducted in France and Germany, with a report from the Committee on Methods of Balloon Surveying.

Supplement M of Appendix 16 contains an illustrated description of the Wagner Tachymeter and Tachygraphometer, as made by Otto Fennel at Cassel, Prussia, an elaborate instrument for stadia surveying and for leveling by vertical angles.

Very Truly Yours
E. S. Chesbrough

Life Member, Western Society of Engineers.

Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XIII. MARCH, 1894. No. 3.

This Association is not responsible for the subject-matter contributed by any Society or for the statements or opinions of members of the Societies.

ISAAC COLLINS CHESBROUGH.

A MEMOIR.

BY ISHAM RANDOLPH, L. E. COOLEY AND BENEZETTE WILLIAMS,
Committee of the Western Society of Engineers.

[Read March 7, 1894.]

THERE are men who honor any calling or profession to which they elect to devote the service of their lives, and such an one was the subject of this memoir, Isaac Collins Chesbrough.

Mr. Chesbrough was born on the 14th day of December, 1814, in the city of Baltimore, Md., and on the 28th day of January, 1893, he breathed his last in his home in Copake Iron Works, New York. He was the second son of Isaac Marks and Phronia Jones Chesbrough, who also gave to the engineering profession that distinguished apostle of its theories and practice, the admired and lamented E. S. Chesbrough.

The subject of our sketch was present at the breaking of ground for the Baltimore & Ohio Railroad on the 4th of July, 1828. The shovel was wielded by the venerable Charles Carrol, of Carrolton, then in his 90th year, and almost too feeble to perform the part assigned him.

When the first car was run over the first mile of completed track, the motive power was a horse belonging to Mr. Chesbrough's father; and he used to say that he was the first way-passenger on the B. & O.; for on this trial trip the car was stopped and he was invited to "get

aboard" and join the select company of those who were enjoying the novelty of riding on the rail.

The next year Mr. Chesbrough entered the engineer corps of the Baltimore & Ohio Railroad as rodman under Mr. George W. Whistler. He remained with that Company until 1830. It is of interest to mention that for the work now performed with the transit, Mr. Chesbrough was taught to use an instrument invented by Colonel Long, the Chief Engineer, and by him called a "goniometer."

From the Baltimore & Ohio Mr. Chesbrough followed Mr. Whistler to the Baltimore & Susquehanna (now the Northern Central) Railroad, and remained there until 1833, when he followed Mr. Whistler's fortunes to Massachusetts, and, at the age of nineteen, took charge of the construction of the Canton viaduct, a section of the Boston & Providence Road. After completing the work he was employed on the location of the Western Massachusetts Railroad. An injury received forced him to leave the field and to occupy himself with office work for some time. Upon his recovery he was made Resident Chief Engineer of the road, made the final location and had charge of its construction. Among his contractors were Sidney Dillon and Daniel Carmichael.

On the 26th of December, 1838, he was married to Harriet, fifth daughter of Lemuel Pomeroy, of Pittsfield, Mass.

In 1844 he became Chief Engineer of the Vermont Central Railroad, and left that road in 1847 to take a similar position on the Sullivan Railroad in New Hampshire. With this Company he remained one year. He then bought a home in Pittsfield, Mass., to which he removed with his family. In 1850 he sold that property and bought a home in Copake Iron Works, New York; at the same time buying a fourth interest in the works. This business did not prove profitable, or congenial to his tastes, so he resumed his profession in 1859 as Chief Engineer of the Ohio River Road, which position he held until 1861. In June, 1862, he entered the engineer corps of the Army of the Cumberland under Captain Micheler, of General Buel's command, and witnessed the battles of Shiloh and Corinth. He remained with the Military Engineers only about six months. His eldest son served in the Cavalry of the Union Army from 1861 to 1866.

In 1863 Mr. Chesbrough became Chief Engineer of the Dighton & Somerset Railroad, with headquarters in Taunton, Mass. Later, and until 1873, he was associated with his brother, Mr. E. S. Chesbrough, in a number of engineering works, a part of this time as private assistant in Chicago, and then in charge of work in New Haven and Detroit.

From 1873 to 1877, he was in charge of the Albany Water-works. His last important work was the location of about 75 miles of the Rocky Mountain Division of the Northern Pacific Railroad, from the

head of the Little Black Foot to Spokane. He located the tunnel under Mullen's Pass, near Helena, and designed an original method of crossing a very difficult place known as "Shelby's Gulch," which had presented a very puzzling problem to his Chief Engineer and associates. The first blast in the tunnel above mentioned was made on Mr. Chesbrough's 67th birthday, December 14, 1881. Age abated none of the enthusiasm of his love for his profession, and he bore the hardships of camp-life, and the exposure which it entailed, with a fortitude which proved the vigor of his manhood. This was the last work on which there was an opportunity for him to leave the impress of his ability, and to that ability it remains an enduring monument.

Towards the close of 1890, Mr. Chesbrough was for a short time connected with the work of the Sanitary District of Chicago, but he resigned when his Chief was removed from office by the faction then in power.

The remainder of his days was spent in the quiet enjoyment of his home in Copake Iron Works, where his only daughter resided with him and watched over his declining years.

Mr. Chesbrough's religious affiliations were with the Protestant Episcopal Church, of which he was a member. He was warden of the "Church of St. John in the Wilderness," which was built in 1852 by members of his own and of his wife's family. In this sacred edifice his funeral services were held on the 1st day of February, 1893, and he was laid to rest among his loved ones who had passed on before him. Thus ended a life of long and honorable service, and thus passed from our midst a veteran whose name we shall cherish upon our roll of honor.

CONSTRUCTION OF RESERVOIR EMBANKMENTS.

Remarks at the Meetings of the Boston Society of Civil Engineers, Held September 20 and October 18, 1893.

The Bursting of the Distributing Reservoir at Portland, Maine, August 6, 1893.

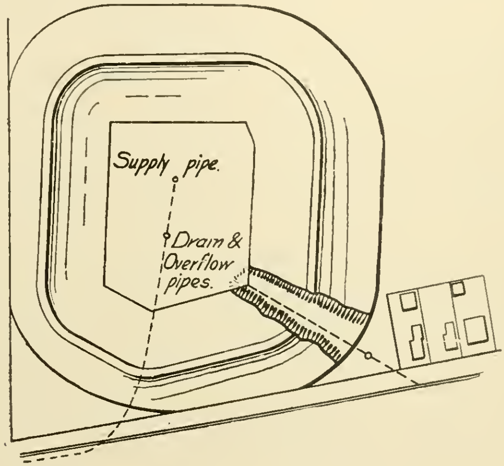
By John R. Freeman.

The reservoir on Munjoy Hill, on the eastern side of the city of Portland, was constructed in 1888 and 1889, and formed the principal distributing reservoir for that city. It contained some twenty million gallons, and the area of its water surface, as I remember it, was about four acres. It was perhaps the deepest artificial distributing reservoir of its kind in the country, the water being about forty feet deep. The embankment contained no core-wall, but was formed entirely of earth. Its height was less than the depth of the water in the reservoir, a large proportion of the fill coming from the excavation. The surface soil covering the site of the reservoir lies upon a very compact and well-cemented hard-pan, as excellent a material of its class as I have ever seen, and so thoroughly compacted in its natural state that the powerful out-rushing flood of water cut hardly six inches into it after removing the surface soil. Before the embankment was constructed, a trench about three feet wide by eight feet deep had been cut into the hard-pan to contain a drain-pipe for the reservoir, and, although the washout had removed much of the back filling from this trench, it left its sides and corners standing almost as sharply defined as though cut by hand, so much firmer was this natural hard-pan than the excellent artificial fill. The main body of the embankment was formed of this hard-pan, which was excavated from the interior of the reservoir, disposed in the ordinary manner in layers about six inches in thickness, and then most thoroughly compacted by means of grooved rollers. The surface soil was used for the portion of the embankment lying outside of a vertical line dropped from the outer edge of the top.

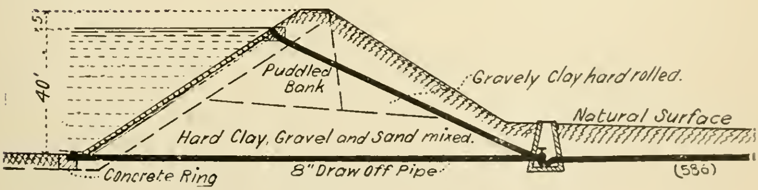
The accompanying cuts indicate the form of the reservoir and of the embankment. The sectional view indicates a somewhat sharper line of demarkation than actually existed between the "puddled bank" and the "gravelly clay bank rolled," for in point of fact both parts were constructed simultaneously, and the same 6-inch layer extended entirely across. I am told that the degree of wetting and of rolling was the

same throughout, and that the only distinction between the two parts was this: that the inspector on the bank ordered those carts which were loaded with surface soil or with pebbly gravel to dump outside the line indicated. The cut also fails to exhibit with distinctness the vertical outer face of the concrete block around the overflow pipe.

After the work on the reservoir had proceeded to a considerable extent, Mr. J. Herbert Shedd, the engineer in charge, fearing that an embankment formed from this pulverized and re-compacted hard-pan



PLAN OF RESERVOIR.



CROSS-SECTION OF RESERVOIR BANK.

alone might not prove sufficiently impervious, substituted a puddle formed by mixing two parts of the hard-pan with one part of blue clay, brought across the Back Bay from the town of Deering. Both ingredients were spread upon a level bed, thoroughly cut up, and then mixed and turned over by means of disk harrows.

The excavation for the reservoir was carried down some four feet deeper than the final bottom, and this space, four feet deep, was very carefully refilled with the puddling material of hard-pan mixed with clay, just described, which was also carried up the slope of the embank-

ment, forming an impervious sloping puddle wall or internal lining six feet thick.

So far as the embankment itself was concerned, it was remarkably well built. The contractors were experienced and skillful, and the engineering supervision appears to have been of the very best.

Two pipes passed through the embankment at the point where the rupture afterward occurred; both of ordinary tar-coated bell and spigot cast iron water pipe. One of these, called the draw-off pipe, was an 8-inch pipe, provided with frequent cut-off walls and laid about a foot below the bottom of the reservoir. The other, called the overflow pipe, was a 12-inch pipe, without iron cut-off walls.

The overflow pipe, at its upper end, was imbedded in a six-foot cube of concrete. Although it was not provided with cut-off walls or with special stops to prevent water from flowing between it and the surrounding material, the evidence obtained at the Coroner's inquest showed conclusively that the work of imbedding it was done with great care.

The reservoir, during the four years of its service, was a remarkably tight one. The Superintendent of the Water-works repeatedly examined the feet of the slopes without finding the least signs of seepage. He reported that the grass on the slopes suffered as much from the summer's drought as that in the neighboring fields, and so free was the foot of the slope from moisture that the grass nowhere grew rank, nor was a bunch of water-grass to be found anywhere at the foot of these slopes. The superintendent had made a circuit of the foot of the slope only a very few days before the accident, and had found everything looking well.

The disaster occurred early on a Sunday morning. It was first noticed by a little girl, who thought she had found a spring. A lady, who was with her, and who lived in a house about a hundred feet distant, saw at a glance that the reservoir was leaking, and, with great presence of mind, warned those who lived in the two houses which stood directly in the path of the stream. Those in the upper house had time to rise and dress and to make their escape; but those in the lower house, after leaving it, returned and remained in it, apparently debating what to do, until the house was carried away and they were drowned. Both the houses appeared to have been of frail construction, and both collapsed under the action of the torrent, which was then probably three feet deep.

The testimony of the successive witnesses is interesting as indicating the rapid, progressive character of the break. On the evening previous one of the men whose home was destroyed had stood for some time, leaning against the fence close to where the break occurred;

another, returning home after midnight, directly across the course of any possible leak, noticed nothing wrong. While the little girl who first noticed the leak mistook it for a small spring, the next person who noticed it described it as a stream spurting out from the foot of the slope and as thick as a man's wrist. An observer, three to five minutes later, found it a little less than a foot in diameter; the next, as large as a hogshead; while the next observer reported the break as being almost large enough for the passage of an ox team. All this took place within twenty minutes from the discovery of the "small spring."

The break evidently began at the foot of the slope, just over the lower end of the over-flow pipe, and in about ten or fifteen minutes the opening had extended to the top of the embankment. In from fifteen to twenty minutes about twenty-five or thirty feet in depth of water escaped, leaving a depth of only some nine or ten feet in the reservoir. The testimony showed that the embankment over the breach formed a natural arch, which did not fall into the breach until the latter was fifteen feet or more in width, a fact which shows the tenacity of the material in the embankment and the solidity with which it was compacted. The caving-in of the upper portion of the bank partially stopped the leak and prevented the escape of much of the water.

The theory which I offered at the inquest, in explanation of the break, is as follows:

During the extremely cold weather which occurred about Christmas, in the previous winter, repairs which were being made on the intake at Lake Sebago, the source of supply, caused the water in the Portland reservoir to be drawn down more than twenty-five feet. Naturally, the wet clay embankment, being thus uncovered, was frozen; and the consequent expansion, acting upward against the thirty-six square feet of the bottom of the concrete block in which the upper end of the over-flow pipe was imbedded, acted with enormous pressure upon this pipe, and must have tended to loosen its contact with the surrounding earth bank, particularly underneath the pipe. When the reservoir was subsequently filled, the water-surface froze over probably one or two feet thick, and the water level was continually fluctuating, so that the ice was repeatedly drawn down and then forced up again. The ice, falling on an incline against the sloping sides and subsequently rising, might act like a toggle-joint and exert great horizontal thrust as it slowly rose. Considering this and the expansion of the ice in forming, it is easy to conceive that a great pressure was thereby brought to bear against the nearly vertical face of the concrete block, sufficient, perhaps, to loosen its contact with the surrounding clay.

Another cause which may have operated to bring about the disaster was the following: As already stated, the embankment was carried

up in 6-inch layers. In order to have a clear roadway for the roller, it was made the practice to plug the upper end of the overflow pipe, as far as laid, and to carry on the filling beyond this, as though the pipe were not to be laid further. After, say, ten or twelve layers had been placed in this way, a wedge-shaped trench was cut down though them for the continuation of the pipe. After the pipe was thus laid, the trench was filled in with the best of the puddling matérial, taking care to use *plenty of water* with it, so as to do, as one of the contractor's foremen testified, " an extra good job of puddling."

Undoubtedly there should have been cut-off walls along this pipe, but this was one of those cases where, as Artemus Ward puts it, " hind-sight is a great deal easier than fore-sight ;" and it is easy now to appreciate the difficulty of satisfactorily ramming the material directly under the pipe where the trench was deep, and to see that ramming hard under the sides of the pipe might result in wedging the pipe up a little from its proper position, thus preventing it from having a firm bearing upon the bottom.

I have often had occasion to note the tendency of water to follow along a plate-iron penstock imbedded in earth ; and my impression is that it is very common to find a thin stream of water running under water pipes in city streets where the grade is steep, and this again shows the difficulty of making a thoroughly tight job in compacting earth against the bottom of a pipe.

Again, the wetness of the material used for re-filling this trench seems to offer an explanation of the catastrophe, for it is very probable that the excess of water in the filling material was absorbed by the dryer earth in the sides of the trench, leaving the filling to shrink. If in shrinking it left a crack no thicker than a sheet of paper, this might in time enlarge, with disastrous results.

Some years ago Mr. Fitz Gerald made a series of experiments with dry and moist earth compacted in wooden boxes, and these experiments showed a strong tendency on the part of the freely wetted earth to shrink away from the sides of the boxes after the excess of the water had disappeared.

There is a gate house just outside of the reservoir, but no gate chamber proper within the reservoir. The testimony showed very clearly that prior to the construction of the reservoir there were no natural springs at or near the point where the break occurred. The height of the embankment at that point was considerably less than at the next corner to the north, owing to a declivity in the natural surface. The embankment was twenty-five feet in thickness at the high water line, and both the wet and the dry slopes were $1\frac{1}{2}$ to 1.

The waste pipe, eight inches in diameter, had frequent cut-off walls and was left uninjured.

About an hour after the break occurred, the paving of the slope on two opposite sides began to slide, while that of the other two sides remained intact. On one of the sides where sliding occurred, the paving, for about seventy-five feet in length, took suddenly much the same form as did that in the reservoir at Lowell, which slipped down into the reservoir when the water was lowered rapidly some five or ten years ago. This sliding, while it throws no light upon the cause of the accident, is interesting and instructive, as showing what may happen with a slope paving on a puddle wall laid with so steep a slope as 1½ to 1, and seems to argue very strongly for vertical as against sloping puddle walls. The ring of concrete at the foot of the slope paving yielded and tipped inward, and the slope puddle, slope paving and all slid down in a confused mass over a space more than 50 feet in diameter.

DISCUSSION.

Professor William Watson.—The carrying of water mains through a mass of masonry in earthen dikes destroys the homogeneity of the latter; for on both sides of this mass the earth must be hand-rammed and therefore imperfectly compacted, no matter what pains are taken, and the settlement of the surrounding earth leaves spaces which may cause dangerous leaks.

In this connection I would call attention to the construction of the Torcy-Neuf reservoir in France, which I have described and illustrated on pages 614 and 615 of the recently published Civil Engineering Report of the United States Commission to the Paris Exposition.

Here the water, instead of being conveyed directly into the mains passing through the dike, is let into a tower which rises from the foot of the inner slope, as shown in Fig. 62, p. 616, of the report. The tower well terminates in a cylindrical chamber, 2 meters in diameter and 2 meters deep, the object of which is to break the destructive shock of the water upon the masonry.

The guard sluice at the bottom of the tower may be closed at any time, and the culvert under the dike can then be easily repaired if necessary. The sluice is so constructed that, notwithstanding the great pressure (27,000 kilograms) of the water, and the weight (2,000 kilograms) of the sluice itself, it is easily operated by a jack of 750 kilograms.

The Classification of Granular Materials.

By Robert H. Richards.

In connection with the subject of earthen dams it may be of interest to notice the methods employed in the process of ore dressing for assorting the sizes of granular materials, and those for similarly assorting clays of different textures.

For coarse materials a series of sieves is used, beginning, perhaps, with a sieve of 2 meshes per linear inch, and following with sieves of 3, 4, 5, 6, 8, 10 meshes, and so on. A sand which passes, for instance, the sieve with five meshes to the inch and is retained by that with six, is called No. 6. A table is then constructed by which the proportions of the different sizes are noted.

The accompanying figure represents the sorting tube employed in Schöne's apparatus for the mechanical analysis of clays, as described in Kerl's "Thonwaarenindustrie." In this apparatus the fineness of the particles is determined by their rate of falling through water, as indicated by the velocity of an upward current which can lift and carry them.

Water, supplied from an overhead tank to the tube A, is led downward through the bent tube and up through the sorting tube C to the gage F. The gage tube EF is open at both ends. At the elbow E is a pinhole through which the water escapes, the rate of discharge at E and the upward velocity through the sorting tube C being determined, of course, by the head shown on the gage F, and regulated by the faucet B. The tank is provided with a very carefully-designed attachment for maintaining a constant head. The sorting tube C, although shown in the figure as tapering throughout, is in reality cylindrical from the widest point, near the neck, down to about the point C.

When a material is to be tested, sufficient water is admitted by the faucet B to fill the sorting tube about to the level of C. The stopper D, with the gage tube, is removed, and the material to be tested is washed into the mouth of the sorting tube by means of a wash-bottle. The stopper and gage tube are now replaced.

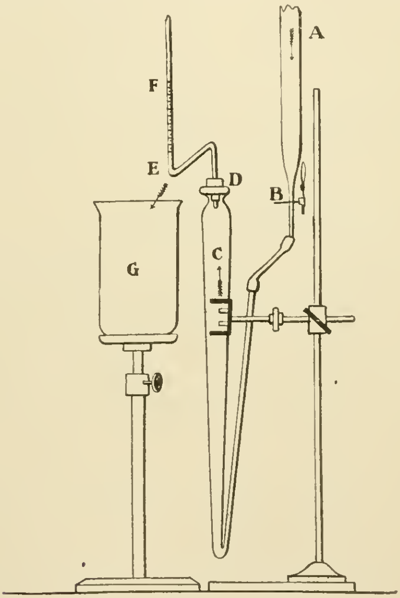
The faucet B is then slightly opened, establishing an upward flow at a very low velocity through the sorting tube C and a discharge through the pinhole E of water carrying in suspension the lightest particles. This discharge takes place under a head corresponding to one of the lower divisions on the gage.

When all of the particles capable of being carried at this velocity have been washed out of the material under examination, clear water issues from the pinhole E. The flow is then stopped, the beaker G

removed, an empty beaker put in its place, and by opening the faucet *B* the flow is re-established at a rate corresponding to a higher division on the scale.

The solid contents of each beaker-full of water are then weighed, and the proportions of material of the different finenesses are thus obtained.

A clay which is to be tested is first boiled in water, then sifted through a sieve with holes 0.2 mm. in diameter, and washed on the sieve until the water runs through clear. The residue left on the sieve is dried and weighed, and, if desired, may be further sorted on coarser sieves. The turbid filtrate is allowed to set in a shallow dish. The supernatant liquor is kept and added to the finest slime overflow or



pure mineral clay from the sorting tube, while the coarser slime which has settled out is used for the experiment.

It is found that a pure mineral clay, with particles 0.01 mm. in diameter, is carried over by a velocity of 0.18 mm. per second, and particles of mineral dust from 0.01 to 0.04 by a velocity of 1.58 mm. per second; while particles from 0.04 to 0.2 mm. are left in the tube. Particles larger than 0.2 mm. are, of course, left on the sieve having measures of that diameter.

Dana states that clay consists of flat, hexagonal scales, and that their form is the cause of the plasticity of the clay. All mineralogically pure clays are hydrated silicates of alumina. The usefulness of clay puddle, as such, depends upon the continuity of its layers.

The Use and Abuse of Water in the Construction of Reservoir Embankments.

[CORRESPONDENCE.]

Boston, Mass., September 2, 1893.

James H. Harlow, Esq., Hydraulic Engineer, Pittsburg, Pa.

Dear Sir:—It is proposed to discuss, at the next meeting of the Boston Society of Civil Engineers, to be held on the 20th inst., the construction of reservoir embankments.

On the occasion of the convention of the American Society of Civil Engineers at Chattanooga in 1891, you told me of some very interesting views of your own, respecting the proper degree of moisture to be used in puddling or in constructing a reservoir embankment.

If I remember rightly, you held that the earth should be packed as dry as possible, on the same principle that guides a carpenter in selecting dry rather than green lumber for making a tight tank, and I think you said that you had constructed one or two banks in this way and that you had seen no reason to regret it.

The matter is, it seems to me, a very important one, and one which might well be brought to the attention of our members.

I am satisfied that one of the causes which led to the recent failure of the reservoir at Portland, Me., was the laying of the overflow pipe in a trench cut in a closely compacted embankment and afterwards filled with a puddle of $\frac{1}{3}$ clay and $\frac{2}{3}$ puddling-gravel, rammed in with a considerable excess of water. Although the puddle was perhaps not left in that almost jelly-like condition which is often advocated by men who wish to do "an extra good job of thorough puddling," I am yet inclined to believe that when, in the course of time, the excess of water was absorbed by the surrounding earth, the puddle tended to shrink and crack, so that a stream of water from the reservoir was allowed to follow the outside of the overflow pipe through the bank.

Many other matters in connection with reservoir banks may suggest themselves to you, as, for instance, the desirability of a more accurate definition of clay and of gravel. I have seen a material which was called clay, but which really contained more than three-fourths of fine river silt and only a little clay, so that, although it looked like clay in the bank, it would, on the addition of water, become a treacherous quicksand. Perhaps you can give us some good rough-and-ready rule for determining the proportion of clay and of silica in a given sample.

Another question upon which you may be able to throw some light is, whether or not a somewhat loose and gravelly material cannot be

made into a safer bank than one which packs and cements firmly. The point made in favor of the loose material is that if an opening is started in it, some of the fragments above will detach themselves and stop the gap, whereas a hard cemented material may remain arched over the opening until this assumes dangerous dimensions.

Very truly yours,

JOHN R. FREEMAN.

PITTSBURG, PA., September 12, 1893.

JOHN R. FREEMAN, ESQ., President Boston Society of Civil Engineers, Boston, Mass.

DEAR SIR:—Replying to your favor of 2d inst., I would say that more than twelve years ago I discussed the construction of reservoirs with Mr. Charles Hermany, of the Louisville water-works, and it was during this discussion that I first received the suggestion of the advisability of building reservoirs with the material taken from the excavation, deposited in thin layers, and thoroughly rolled without the addition of water.

Mr. Hermany claimed that the material, when thoroughly wet, could not be so compactly rolled as when in its natural and simply moist condition, and that the subsequent drying out of the water would leave greater voids than if the material had been put in dry.

Within the past few years I have built five reservoirs without sprinkling the banks during construction. The material was placed in thinner layers than usual, and the rolls were kept constantly going. I have seen no reason to doubt that this method is as good as the usual one of wetting the material.

The material in this section contains more clay than does that found in Massachusetts, and when it is excavated after a long, dry spell, it is apt to come up in large lumps. If placed on the banks in thin layers in its natural condition and thoroughly rolled so as to pulverize the lumps, the absorption of water upon the filling of the reservoir causes the material to swell, and, in my opinion, to make a tighter bank than when the material is put in wet.

The material used in reservoir embankments, of course, varies greatly, and the selection of the best method of working it in any given case is necessarily a matter of judgment and experience. Some of the tightest coffer-dams I have made were filled with material dredged from the bars below the dams of the Monongahela River. This material would at first sight be taken for a very coarse gravel, but it undoubtedly contains much fine stuff, and possibly clay.

I find the behavior of such material, as compared with clay, is just

as you state, the former having a tendency to fall in and stop a gap while the latter may remain arched over it. One of my contractors filled a coffer-dam with clay taken from the banks of the river, believing, no doubt, that clay would make a tighter dam than any other material. Some time after the dam had been built a small hole was accidently discovered in the filling, next to the inside sheathing. The sheathing was partly torn away to admit of repairs, and it was then found that the hole was quite large. Fortunately it did not extend through to the outside sheathing or to the top of the filling. The clay had arched itself over the opening and the work going on above it did not break it through. I should estimate that two cart loads of material were required to fill the hole.

Another advantage of gravelly material is that when it caves in and stops the opening, it thereby gives notice of the fact by the settlement at the upper surface, whereas the clay, remaining arched, gives no sign of the injurious work that is going on below, and the first indication is apt to be a break in the coffer-dam. I know of no rule for determining the proportions of clay and of sand in a given specimen.

Yours truly,

James H. Harlow.

Pittsburg, Pa., September 16, 1893.

John R. Freeman, Esq., President Boston Society of Civil Engineers, Boston, Mass.

Dear Sir:—Upon receipt of your favor of 2d inst., I forwarded to Mr. Hermany a copy of my proposed reply, asking him to suggest any required amendment, and to add any further points of interest which might suggest themselves. To-day I am in receipt of his reply and I now forward it to you.

Referring to this, I may add that during the last few years my practice has been to make the reservoir bank practically uniform, except that I select the best material for the inner half of the bank, leaving the poorer material for the outer half, in order that if the water should by any means penetrate through the bank to the outer half, the sooner and easier it gets away the better.

Respectfully yours,

James H. Harlow.

Louisville, Ky., September 18, 1893.

James H. Harlow, Esq., Consulting Engineer, *Times* Building Pittsburg, Pa.

Dear Sir:—My views respecting reservoir banks are imperfectly outlined in two specifications of 1876 and 1884 respectively, copies of which I mail you herewith.

The method of constructing a reservoir embankment must always be governed by the conditions of the case, as to locality, character of material and height of embankment. As a general rule, however, I feel safe in saying that the embankment can and should always be so constructed that while the *foundation* may or may not be compressed by the load of the artificial embankment, which may therefore settle as a whole, the embankment itself shall not settle under the pressure of the water or have its volume diminished by it.

An embankment so constructed with material in its natural moist condition, will not afterward become saturated with water except by capillary attraction, and the water so absorbed will not cause a leak or a shrinkage in the volume of the bank. The application of puddle upon the slopes of the bank, or in the form of an interior core-wall, is not only superfluous but is absolutely detrimental to the durability of the construction taken as a whole.

The reservoir constructed under the specifications of 1884 is an earthen embankment built of a very inferior material, consisting of a light loam which contains a little clay. Upon saturation of water it becomes a fluid rather than a mastic; that is to say, it compares with what I consider good material as sawdust compares with sand. If a body of sawdust is slowly saturated with water, its particles are agitated and tend to rise, separating from one another and increasing the volume of voids, whereas if a body of sand is similarly saturated, its particles will subside, approximating to each other, and thus reducing the volume of voids. The banks of the reservoir in question proved to be perfectly water-tight.

In your letter to Mr. Freeman you have correctly outlined my views on the subject, as expressed to you on the occasion referred to. In the foregoing I have indicated such modifications as those views have since undergone.

You will notice that in the specifications of 1876 I used the expression, "earth puddle," instead of the ordinary term, "clay puddle." I made this distinction because, in my judgment, it is a misnomer to apply the term clay puddle to any of the materials which I have seen used for puddling purposes.

Like the ghost of Hamlet's father, the ideas prevalent among engineers with reference to puddle and to its office in hydraulic construction, come in questionable shapes. There is great need of a better classification of the materials used for making puddle, and of greater knowledge respecting the best method of making and using it.

Very respectfully,

CHARLES HERMANY.

The following extracts cover the more important points referred to by Mr. Hermany in the specifications mentioned in his letter:

SPECIFICATIONS FOR CONSTRUCTING SAYRE HILL RESERVOIR, FRANKFORT, KY., SEPTEMBER 1, 1884.

Upon the site, after it has been cleaned off as specified, the construction of the embankment is to commence by grading the sloping ground into level contours or steps of about four inches rise, and such widths as the rate of inclination in the surface of the ground will make necessary. The grading and stepping is to commence at the lowest outside margin of the banks, and to be carried up until they are level all around the basins. Thence to completion they are to be carried up uniformly in layers, which are to be level, both transversely and longitudinally, with the banks, and each four inches thick when loosely spread; the best material always being placed in those parts of the layers next to the water slopes of the banks.

Each layer is to be rolled with two grooved rollers of two different weights, one weighing one hundred and sixty (160) pounds per inch of tread, and the other three hundred (300) pounds. The rolling is to be done in directions parallel to the axes of the banks, and every part of the surface of each layer is to have not less than six separate passages from each roller, light and heavy. Such portions of the embankments as cannot be rolled shall be rammed by hand so as to make them as solid as the rolled portions.

Each layer of earth shall be watered at such times and to such an extent as the condition of the earth and the state of the weather make necessary for a thorough uniting and incorporating with its predecessor in the banks. The water must be applied with hand-hose fitted with rose jets, or by carts similar to carts used for sprinkling streets.

No objection will be made to any degree of dryness in the earth when brought upon the embankments; but when from any cause whatever the earth is so moist or wet as to become spongy under the rolling process, it will not be admitted into the embankments. The embankments must be built full to the forms and dimensions given. Any overfilling which may happen from any cause, must be trimmed off to reduce the banks to stipulated dimensions, but will not be paid for. On the water side the slopes must be rammed by hand, so as to become as solid as the rolled portions of the embankments. No puddled earth is to be used in the construction of the embankments for the purpose of making them hold water, but the skill, solidity and fidelity with which they are constructed will alone be relied upon for their being water-tight after completion.

SPECIFICATIONS FOR CONSTRUCTING CRESCENT HILL RESERVOIR, LOUISVILLE, KY., 1876.

Each layer shall be solidified by being rolled with gangs of grooved cast-iron rollers, each gang weighing not more than four tons. The rolling must be done in directions parallel to the length of the embank-

ments, and distributed uniformly over each layer. The degree of solidity to be imparted to the embankments by rolling will be determined as the work progresses, but in no case shall there be less than ten miles of roller travel for each one thousand cubic yards of earth put into the embankments. Such portions of the embankments and fills as cannot be be compacted by rollers of the weight named, must be rammed by hand so as to become equally solid with the rolled portions.

The requirements for watering are the same as in the Frankfort specification just quoted.

No objection will be made to any degree of dryness in the earth when brought upon the embankments and fills, but when, from any cause whatever, the earth is so moist or wet as to become spongy under the rolling process, then it will not be admitted into the fills and embankments.

Earth puddle will be laid upon the bottom of the basins, on the inside slopes of the embankments, around the gate-house walls, and at other points where it may be deemed necessary. It must be laid on in conformity with the shapes and dimensions given on the plans.

Puddle is to be made of the best material to be found in the basin, or borrow-pit excavations. The different kinds of material to be used—loam, clay and gravel—must be brought together from the basin and borrow-pit excavations and mixed. The mixture then is to be watered and tempered so as to make it into a paste of uniform density, and somewhat stiffer than brickmaker's clay when being moulded into bricks. The tempering must be done by hands and feet, by pug-mills or by brick-clay tempering wheels. When the puddle is being put in place it must be *as stiff and as free from water as is admissible for a complete uniting of each layer with its predecessor in the work.*

Those portions of the inside slopes of the banks which result from excavation, and which have not had the benefit of rolling, are to be left full, and afterwards rammed by hand and carefully solidified before the slope lining of the basins is placed thereon.

DISCUSSION.

By Desmond Fitz Gerald.—The subject under discussion is naturally divided into two parts: First, the proper method of laying pipes through reservoir embankments; second, the construction of the embankments themselves.

The failure of reservoirs by reason of the pipes passing through them results usually from laying the pipes naked through the banks; from the improper design of the puddle around the pipes; by subsidence and breaking in the center of the embankment due to the great weight at that point, or from placing the pipes upon piers of masonry without continuous support.

If pipes are to be enclosed in puddle, there should be as little as

possible under the pipes, and it should be distributed uniformly along them. If it is unequally distributed there will be unequal settlement and liability to fracture. Even under the best conditions and with ample cut-off walls, the idea of puddle in connection with a pipe has never appeared attractive to me. In the case of Dam No. 6, of the Boston Water Works, I have placed the pipe on a continuous ledge foundation and surrounded it with brick masonry and with plenty of cut-off walls. Where pipes under pressure are continued below the dam I put them in a tunnel closed by a heavy bulkhead. In this case they can be examined, and, if leakage occurs, the joints can be calked. By using sleeves instead of the ordinary joint, any given length of pipe can be taken out without disturbing the others. There have been some instructive failures of reservoirs in England.

Humber condemns the practice of increasing the depth of puddle under those parts of the pipe or culvert where the superincumbent pressure is to be the greatest, and cites, as an instance of this, the dire calamity resulting from the failure of the Dale-Dyke reservoir of the Sheffield Water Works.

In one of the Liverpool reservoirs two lines of 44-inch pipes gave way by settlement.

It seems to me that puddle should be used only where it can be kept always wet. If it drys out there must be shrinkage. I have seen striking illustrations of this.

My experiments, and alluded to by the President, were made several years ago in connection with observations on evaporation from the ground. I had to fill eight large tanks with gravel, sand, earth, mixtures of puddle and other materials, as ordinarily found in nature. It was necessary to cut off all percolation down the sides of the tanks, which were lined with zinc. In all cases where the materials were deposited wet I found that it was impossible to keep the tanks full, no matter how much ramming was done, but by ramming dry I avoided all trouble from shrinkage. After the tanks had been in use for several years I had holes dug, and in every case the material brought the paint off from the zinc when it was removed, so perfect was the connection.

Earth embankments may be broadly divided into three classes: (1) Homogeneous embankments; (2) Embankments with puddle or core-walls in the center; and (3) Those with the puddle or concrete on the inner slope. The papers that have been read have already shown the great diversity of opinion as to the best method of construction. As in most other engineering works, local conditions should largely govern design; but there are certain broad principles which must, to a certain extent, control in all cases.

I heartily agree with what has been said in regard to the necessity

of building up an embankment with very thin layers in order to compact the material thoroughly. In the case of Dam No. 6, I have made the layers 4 inches in thickness. The dams of the Boston Water Works are generally built with a core-wall of concrete in the center, backed up with puddle or fine material on the water side. The wall is provided with buttresses to stop the longitudinal passage of water, and the up-stream surface is carefully plastered with Portland cement. The core-walls are, in some instances, nearly 100 feet in height. The earth slopes are generally two to one, and are protected in the usual manner. Four years ago I introduced into the middle of the down-stream slope of a high embankment a berm with longitudinal drainage to protect the loam covering until the grass could become well rooted. So far as I know, this was the only instance of the kind in this country at that date.

The best English practice is to make the water slopes three to one, and the outer slopes two to one, and to put the puddle walls in the center of the embankment. One of the speakers this evening said that no good reasons seem to have been given for putting the puddle in the center. I will mention briefly some that occur to me, although they may not be wholly satisfying. For the same money more puddle can be put in a vertical wall than on a slope of equal height. A puddle-wall in the center of a bank is not exposed to the danger of slipping when the surface of the reservoir is suddenly drawn down. I am aware that this is not so liable to occur with canals as with reservoirs; but I have seen several accidents of this kind in the latter case. The water does not seem to work out of the puddle quickly enough to drain the bank, and the result is a *head*, which caves the slope. Puddle in the center of an embankment is less exposed to frost, to drying out and to cracking than it is on the slope.

It has been maintained this evening that an embankment should be homogeneous, but the practice of some very good engineers in India is the very reverse of this. They make the bank of fine material on the inside, gradually changing to a mass of rubble on the outer or down-stream side. On the Toonskasala canal, about 200 miles long, there were some embankments 50 feet in height. According to Mr. Hawkshaw, valuable experience was gained in connection with failures in these banks, which, I think, were at first constructed with central puddle walls. The banks leaked so frequently that great expertness was acquired in repairing them. A hole as large as 2 feet 6 inches in diameter could be stopped by pouring in gravel and sand. After much experimenting it was decided that in order to build a safe bank it must be constructed on the principle of the filter. On the side next to the water is placed fine sand, then coarser sand followed by gravel, and finally stones. It is argued that any leak in such an embankment must

pass off harmlessly. To make it as tight as possible it is only necessary to add puddle on the inside face over the fine sand. In order to keep the puddle from cracking, a cushion of fine earth may be rammed wet between it and the filling.

Embankments 200 feet in height have been thus designed, but I do not know that any have been built.

In our embankments on the Boston Water Works we always place our coarsest material on the down-stream side.

By Clemens Herschel.—An urgent invitation to join in the symposium of the Boston Society of Civil Engineers on the construction of reservoir embankments finds me little disposed to do so in writing. This is a subject in which theory and its discussion must play a part subordinate to that of judgment trained by sight and touch in the actual handling of earth and gravel. The characteristics of the materials to be considered, although clearly enough impressed upon the mind of the practitioner, are not readily defined in writing. Recent experience in the discussion of a kindred subject in a kindred society has shown, for example, that widely differing notions prevail, even as to the meaning of the word "gravel;" apart from the fact that even though the general application of the term be settled upon, there yet remain many kinds of gravel. Similarly, there is a multitude of clays, and of other soils, which, in many cases, differ but little, as far as a written description could identify them, though they may differ ever so widely in their qualities or in their behavior.

In employing so crude and incoherent a material as earth for holding water, the writer believes, primarily, in striving to obtain homogeneity. If that is not wholly attainable, there should at least be no sharp dividing lines within the structure in passing from one kind of earth to the other.

To illustrate: Suppose the slopes of a reservoir embankment to be constructed like a sand filter, passing, in cross-section, from coarse to fine material, each layer, however, being homogeneous within itself. Such a bank would, at first, leak like a sieve, but uniformly, and without detriment to the embankment, if only care be taken not to allow the water to pass through at a dangerous velocity. And such an embankment, if kept supplied with silt-bearing water, a little of its height at a time, would as certainly become water-tight as the ordinary filter clogs up and becomes water-tight.

Of course, this is supposing an extreme case; but the consideration of extreme cases is often the readiest means of discerning an underlying principle.

Dikes upon the seashore are often built on pure sand, as was that built at Provincetown by the Commonwealth of Massachusetts, under the direction of Mr. James B. Francis, and now forming part of the road-bed of what was lately the Old Colony Railroad. Nothing saves such a bank from destruction but the homogeneity of the material it stands on. Were this clay, with veins of gravel, or clay fissured with cracks, or fine gravel with seams of coarse gravel running through it, such a dike would not stand a week; if fissured rock, the dike or dam would stand, to be sure, but would be said to leak, although, strictly speaking, the leakage would be that of the rock foundation, and would, under ordinary heads of water, be minute. The fissures would probably clog up in course of time, and the leakage, while it continued, would ordinarily be of no consequence. There is, however, a case on record where a high dam in Algeria was destroyed by leakage through seams in the foundation rock.

If it be necessary to use permeable material for the dam, as well as for the foundation, a row of placed (not driven) sheet-piling in the center, will make the dam tight; and, ordinarily, the water side of the dam will become silted up before the sheet-piling has had time to rot away.

The Provincetown dike is not only built *on* sand, but also built *of* sand, and with a row of sheet-piling in the center. The canal banks at Holyoke, Mass., which consist of permeable fine sand or silt, and which stand on silt, offer another example. When saturated with water this silt is popularly called "quicksand." When the canals are drawn this "quicksand" becomes a material that will stand perpendicularly, or overhang in excavation, and which can be cut like cheese.

A row of sheet-piling, placed behind a dry canal wall of rough stone, is all that has ever been found necessary to make such a canal bank water-tight, even when the adjoining mill site is on a level with, or slightly below, the bottom of the canal. I judge that in the course of forty years this sheet piling disappears, or becomes humus; but, long before that time the sand filling between the sheet piling and the water has been completely silted up and has become water-tight. Still, it is treacherous stuff, and the works need constant and intelligent supervision to keep them whole.

When excavations are carried below the bottom of an adjacent canal filled with water, the water frequently breaks into the excavation, passing completely under the canal banks.

Mill-wrights have a notion that a layer of blue clay, placed next to sheet piling, exerts a preservative effect upon it; but I have seen cases where old flumes, surrounded with blue clay, have been dug out with a shovel, the shovel serving indifferently to excavate the clay or the flume; and the latter had not been in the ground for an unusual length of time. In high reservoir embankments of the standard *fin de*

siècle American pattern, sheet piling is replaced by a core-wall of either concrete or masonry, founded upon the ledge or upon some other trustworthy substratum below the original meadow level, and extending up to the full water-line. This core is made some 4 or 5 feet thick at top and at bottom, tapering each way from top and bottom to a thickness of 7 or 8 feet at the original meadow level. I have heard these core-walls criticised on theoretic grounds, but I know of no valid objection to them. There is, indeed, on record a case of failure of a core-wall embankment; but in this case the core-wall was but about 5 inches thick, and a section of it served as a paper-weight on an engineer's desk, having been mistaken for a specimen of the concrete composing the core-wall. This case illustrates rather the perversity of human nature than water-works construction. Of course, such freaks as this are not embraced in the foregoing commendation of core-wall embankments of proper form. On each side of the core-wall, the best obtainable soil, capable of being puddled, must be built up in such manner that it *will not* settle, but *will* hold water. To distinguish the fit from the unfit, I have used the expression, "capable of being puddled;" and this brings up the question: "What constitutes puddle?" As I understand the term, puddle is earth duly consolidated by the application of water. In and about Lowell, the fitness of a material for puddling was ordinarily tested by placing in a pail of water enough of it to render the water invisible. The pail was then upset, and, if the mixture dropped out, it was rejected; if it remained in the pail, it was considered satisfactory for puddling. Such a test would evidently exclude garden loam, sea-beach shingle, or pebbles. It would also exclude clay, unless this were most carefully mixed and tempered with the water of the pail.

It is perhaps true that earth can be more thoroughly compacted by packing and ramming dry than by watering and rolling. We must remember, however, that the process used must be adapted to the capabilities of the workmen employed. It would, for instance, be exceedingly difficult to insure that a gang of laborers of almost any class would, by dry ramming, compact 100,000 cubic yards of earth to the same consistency which it would readily assume under the persuasion of a plentiful stream of water from a hose or hydrant and under the manipulation of the same gang of men with carts and rollers which may readily be kept moving over it.

In the various methods which I have here noticed for making water-tight embankments, no clay is employed. It would, indeed, be possible to build a water-tight embankment entirely of clay, but it would be a troublesome and expensive piece of work. This is evident if we consider how difficult it is to make puddle of clay. Clay becomes slimy and sticky when wet, and yet it is difficult to mix it thoroughly with

water. Hence, voids are apt to occur in the body of the puddled mass. As the water leaves it, it shrinks and cracks, and yet retains water in parts; so that it never properly settles down and becomes compact, but is liable to be cut away if only a small stream of water passes through it, or if it is placed in water which is only gently agitated.

Gravel capable of being puddled will do anything that clay was ever used for in water-works practice, and will do it better. I have known cases where clay was brought at considerable expense to a bridge site to be filled into bags and used in coffer-dams, while good gravel, which would have done the work much better, abounded close at hand. Clay, placed in such bags, washes out and disappears, while gravel retains nearly its full dimensions in water.

I have no doubt that clay owes its reputation in this country to its mention in accounts of English work. There is a vast amount of what farmers call "in-and-in-breeding" in the education and training of water-works engineers in the United States; so that when an error of this sort is once engrafted, it is not easily eradicated. I am inclined to think that, as a matter of fact, the use of clay in England for reservoir embankments is due to the scarcity of other material of a suitable character. So far as my observation extends, the practically-taught New England builder of dams and reservoirs wants none of it. He can use it, and he does use it when he must; but he gets along very well without it, and he is never guilty of carting it upon the site of his works.

Professor Richards.—I think that if wet clay is exposed to frost it will be penetrated in all directions by long crystals of ice, resembling sword-blades, and that, when the water is again let on, these crystals will melt away and leave the clay riddled with holes.

By Alphonse Fteley.—I have often remarked the great divergence of opinions expressed by engineers in regard to the quality of materials and to the methods of construction to be adopted for the erection of structures wholly or partially made of earth, and I think that such divergence must be largely attributed to the differences existing between the materials used, which, although designated by the same general names of earth, loam, sand, gravel, clay, hard-pan, etc., may present widely different characteristics of size and composition. Again, the same material acts differently under various climatic influences and under different conditions of water pressure.

Local circumstances, also, have so much to do with the formulation of a proper plan that, in examining a number of structures of apparently similar design, it is generally found that they have differed in details of construction.

Materials and methods of construction which may be proper for embankments behind which the depth of water is to be moderate would not be acceptable for similar structures designed to retain great depths of water.

The amount of percolation which takes place without harm, temporarily or permanently, through certain embankments, would be altogether inadmissible under other conditions. Gravel, for instance, successfully used for a coffer-dam through which some leakage is tolerated, even under a moderate head of water, would be inadmissible in the high embankment of a reservoir from which no leakage must take place, and the failure of which would entail loss of property, perhaps of life.

Gravel, if composed of such variety of sizes that the interstices between the largest pebbles are filled by smaller ones and the interstices between these by the next size, and so on, until the finest particles make a perfect closure, would be an excellent material for making embankments, but this perfection is not found in nature. A satisfactory result is often reached by the closure of the smallest interstices by means of small earthy particles brought by a steady flow of water containing silt, such as is found in canals. This result, however, cannot be expected in the case of banks intended for the storage of clear water, and hence the use of pure gravel for high reservoir embankments cannot be recommended. It is true that if an opening occurs in such a bank the neighboring particles may be washed into it and prevent its enlargement, but in course of time such displacements impair the stability of the mass.

The writer recollects an instance where a dam made entirely of gravel retained a large body of water with a maximum depth of nearly 50 feet. At the lower toe numerous leaks appeared, which probably reduced the elevation of water within the embankments. The dam had stood for forty years, and the evidence seemed to show that the volume of leakage was less than it was immediately after construction. There was no appearance of solid particles in the outcoming streams, and, judging from its antecedents, the structure would probably have stood a number of years; but what engineer could say that its stability would have continued indefinitely?

The writer is of opinion that clay, on account of the fineness of its particles and of what is commonly called its binding qualities, must enter into the composition of the material used. That a very small proportion of it is sufficient is shown by the very excellent behavior of banks wholly formed of hard-pan in which the gravel and fine sand are cemented by the admixture of various proportions of clay.

I now recall an embankment, 50 feet in height, formed of such material. The formation of the bottom of the valley was a coarse

drift, highly permeable to water and 20 feet deep. The removal of this material over the whole site of the dam would have rendered prohibitory the cost of the structure. A trench about 16 feet in width was therefore dug across the valley through the drift, and was carefully filled up with a hard-pan found in the immediate vicinity and containing only a small proportion of clay. Above that trench was laid the embankment, which was formed of the same material. That structure was absolutely tight, and it remains so to-day, after twenty-five years of use, although at the lowest point only 16 feet of the material just described resist the passage of the water.

This instance is given not as one worthy of imitation, but to illustrate the value of a natural mixture of clay with other material.

The artificial puddle formed of gravel and clay in proper proportions has been too often satisfactorily tested to need any additional mention.

Some clays are apt to become saturated with water and under certain conditions to become fissured. They cannot, therefore, be used alone. Moreover, unless a clay is exceptionally tough, an aperture through it, however minute, is apt to become enlarged and finally to cause serious trouble. We find, however, that a number of dams of great height are reported from California as being built of clay. The designer of several of these dams stated that he had subjected a cubic foot of the clay to a hydraulic pressure much superior to that corresponding to the expected depth of water behind it, and had been unable to force water through it; but these clays must be of very exceptional quality.

When the material at hand cannot be worked into an impervious mass, a water-tight lining is often resorted to, made either of masonry or of an impervious clayey mixture, protected from the action of the water by paving. Cases of this kind are on record as having given satisfactory results.

A certain reservoir, the slopes of which are protected by a paving of brick, was excavated in a sand-hill nearly twenty years ago, and it is still in successful service; but the clay or puddle lining, unless well executed with unobjectionable material, may slide, or the impervious paving may be disturbed and cracked by the settlement of the mass which supports it.

When it can be done within proper limits of economical construction, the writer prefers to secure water-tightness by means of an impervious wall built in or near the center of the embankment and continuously connected with the impervious bottom or extended downwards to a safe depth.

Excellent results have been obtained by puddle walls thus placed.

They have the advantage of securing perfect homogeneity with the rest of the embankment, and, if well executed, are justified by good practice.

Foreign engineers insist especially upon perfect homogeneity of the whole mass of an embankment to stand water pressure. In France they carry this idea to such an extent, as regards masonry dams, that they take the trouble of quarrying their stone into small pieces, such as a man can carry, rather than use large blocks which would tend to lessen the homogeneity of the mass of masonry. The same question has been recently agitated in England in a conspicuous case.

There is no question that homogeneity in the mass of an embankment is very desirable; but the writer, with some experience of the difficulty of obtaining perfect work at all times, and of the trifling causes that can produce a leak through an earth embankment, prefers to use a masonry wall as a core. If a small defect exists in the core-wall, only a limited amount of water can find its way out.

It is obviously desirable to use for the up-stream part of the bank as compact a material as can be found, but if no material suitable for this purpose can be procured, the core-wall will secure a satisfactory result. The sliding of the down-stream part of the embankment in case water should find its way through the wall, must evidently be prevented by all possible means. Hence the most porous material, and such as cannot run or be softened under the action of water, must be used in that part of the embankment.

In a recent case which came under the observation of the writer, no porous material being found on the ground, and the down-stream side of the embankment being formed of rather fine material, its lower layers, resting on rock, became softened under the action of a very small volume of water which found its way from the reservoir under the core-wall 20 feet below the natural surface. The bank showed slight horizontal cracks, and the movement was stopped only by a thorough drainage of the rock below the lower toe.

I do not see that the presence of a masonry core-wall weakens the structure in which it is built, for the tendency of the earth is to settle against the masonry. At any rate, I have failed to find, in all the cases of accidents which have come to my knowledge, any that were due to the presence of a core-wall. The cause of the failure was invariably a defect in design or in construction.

In many cases core-walls have been built of too small a section. I once saw a piece of a concrete wall, so-called, from a dam which had been destroyed. The sample showed the full transverse section of the masonry and could be carried in one's pocket. The wall was 4 inches in thickness.

If the embankment on each side of the core-wall is properly carried up there will be little, if any, settlement; but in view of the possibility of settlement, the wall must be of such section as will resist the resulting difference in the pressure of the earth. Such a section can hardly be determined by actual calculation, but, guided by experience acquired by actual practice, I generally give to the wall a width of about 15 per cent. of the height above the section considered.

In forming the embankment on each side, the usual practice of forming thin layers, wetted and well rolled, appears to give good results. I do not think that an excess of water is desirable; for it occupies spaces that may remain unfilled. The use of water in quantities sufficient to give plasticity to the earth and to moisten it to about the same degree as is observed in a deep excavation free from water, is probably the most satisfactory.

A number of dams, built across valleys for storage purposes, have come under the observation of the writer, where great pains were taken to make the embankments as impervious as practicable, and where the foundations under the dam were extended to considerable depths in order to prevent subterranean infiltration, while the penetration of the embankment into the abutting hills was singularly insufficient, and thus filtration, which was studiously and at great cost guarded against at other parts of the structure, was permitted to take place through the side hills around the embankments and through natural ground, often of unknown quality.

As to the proper maintenance of the part of the embankment which is exposed to the air, I think that grass is the best covering. It will, however, hardly maintain itself well on a slope steeper than 2 to 1. It sheds the water well, but, when the height is considerable, it is better to divide the surface by a berm, provided it is well drained laterally. Such drainage must, however, be well maintained; for, in case of its failure, the sod on the lower section of the slope would soon be undermined. If there is any fear that the structure is not to be properly maintained after construction, a continuous slope is preferable. A well-maintained berm at mid-height I consider better than a continuous slope involving the same quantity of material with a slightly flatter inclination.

As some settlement must always be expected in earth embankments after construction, it is obvious that all piping, channels and other structures which are intended to carry water through the earth-work should be built in such manner as not to be affected by movements which may take place in the artificial mass of earth. The safest method is to build these structures in the natural ground adjacent to the embankment. If, owing to the topographical or economical conditions of the case, this cannot be done, the pipe or channel, etc., should be placed on

the natural surface of the ground; only the upper part and the sides of the structure being in contact with the earth-work. It is needless to point to the necessity of bestowing the greatest care on the execution of such work, for a defect, however small, would result in the injection into the work of a quantity of water which might affect the stability of the whole embankment.

Especially in the down-stream side of the embankment, where the water pressure in the pipes is generally much superior to the inward pressure, the danger of a leak is enhanced.

In high earth dams, where the gate house is placed in the embankment, and in continuation of the core-wall, it is good practice to enclose the pipes in an arched masonry structure, so that they may be readily examined.

Water being prone to follow continuous joints, it is also necessary that the water-channels built through the embankment or through the adjoining grounds be surrounded with a number of collars or similar devices for checking such flow.

Constant care and vigilance in the construction of works intended to contain water, cannot be too strongly insisted upon; for a temporary neglect of details may create permanent defects which it is difficult, if not impossible, to remedy after construction. This is especially true of high dams, of distribution reservoirs for cities, and of other costly structures, the failure of which would bring large financial losses, if not consequences of even more serious character. In such cases, the supervision during construction should be ample and of a superior character, and the sums expended for this purpose, although they may, to some, appear excessive, are, in my opinion, well invested.

By E. F. Smith, Superintendent and Engineer of the Canal Department of the Philadelphia and Reading Railroad.—The proper form and dimensions of a reservoir embankment of given height are so well understood that it is unnecessary for me to discuss that feature further than to say that slopes of 2:1 to $2\frac{1}{2}$:1 for the inner, and of $1\frac{1}{4}$:1 to $1\frac{1}{2}$:1 for the outer slope, are to be preferred, the precise inclination varying to suit the stability of the material to be employed and the height of the embankment.

THE RELATIVE VALUE OF CLAY AND OF GRAVEL IN THE CONSTRUCTION OF RESERVOIR EMBANKMENTS.

1. *Clay.*—There are so many varieties of clay, depending upon the origin of the deposits, whether from disintegrated granites, shales and other rocks, that it will not be profitable, except in a general way, to consider their composition and relative fitness as material for the safe

construction of reservoir embankments. The material of river bottoms and deltas, as, for instance, the delta of the Mississippi, is composed chiefly of silt, consisting mainly of extremely fine sand; and, although sometimes called clay, is not so, strictly speaking.

In districts where shales predominate, clay, so called, results from their disintegration. In some places, as in the valley of Virginia, along the slopes of the Blue Ridge and South Mountain, and in Pennsylvania, the shales are usually associated with limestones, which, in turn, are overlaid by sandstones (Potsdam) composed of very minute particles of sand. These and the finely disintegrated shales are often intermingled, and when so found the formation is designated as clay. In the same districts, too, finely disintegrated sandstone (Potsdam), sometimes nearly white, and *free from iron*, is called clay; but, in fact, it partakes rather of the character of quicksand.

The hill slips of the Blue Ridge furnish a similar material associated with iron ore and containing nodules of pure clay, and these form, when intermingled, a clay varying in color from salmon to deep red. This clay is of a tenacious, sticky nature, causing the mass, when subjected to compression, to adhere very closely. If, in addition to the disintegrated shales and sandstones, we find also, as is often the case, the disintegrated limestones, granites and flints of the Blue Ridge and South Mountain with more or less of the iron-ore clays of the Northern escarpment, we have a still better material. It goes by the common name of clay; but it is not pure clay. It contains a great deal of gravel, and this gravel makes it a good material for reservoir embankments.

Fat or unctuous clays are mostly designated by writers on hydraulics as the *only proper material* of which to form an impervious, water-tight wall in the heart of an embankment, or the entire mound of a reservoir, as the case may be; and yet I am convinced that more failures of reservoir embankments and of high earth dams are due to the too free use of pure clay in puddled core walls, and to the almost entire dependence placed upon such walls, than to any other cause.

When engineers appreciate the fact that a homogeneous bank of gravel, compacted by a little clay, is better than a clay core with indifferent material on both sides of it, the number of failures will be comparatively few.

Where true clays are used in proper proportions with other material, they are fitted for the purpose of reservoir construction. In this *I do not include those so-called clays which originate from sand that has been reduced to finely rounded grains, and which rather resemble quicksand.*

Gravel suitable for use as a reservoir embankment may be defined as a material resulting from the disintegration of any of the harder

rocks with the admixture of water-washed pebbles and stones not larger than pigeon eggs nor smaller than the grains of coarse sand, with sufficient clay to bind the mass together when compressed. The presence of a suitable binder, in the form of clay, is the one important element in the make-up of gravel suitable for puddling.

The mistake too often made by engineers is that of supposing that *only* clay can be used for puddling. Some of the best embankments, holding impounding reservoirs of great height, are built entirely of what should be classed as gravel puddling.

An embankment built entirely of clay is an unsafe one, even when puddled in the very best manner possible. It is easily attacked by musk-rats and by other foes of a water-tight embankment. When a leak starts, the tendency of pure clay is to swell; whereas with gravel or sand the opposite is the case, the material breaking down and choking the leak.

The dependence upon pure clay, and especially the blue clays, for puddle material, and their scarcity in most localities, has led engineers into the error of building a clay puddle wall in the heart of the embankment.

Why should the middle of the mound be any better than that portion next the water, as, for instance, the whole inner slope? The proper construction of an impervious bank is to make the whole a homogeneous mass of well-selected material. No dependence at all ought to be placed upon a puddle core in the heart of the bank. Such construction inevitably leads to carelessness in the selection of the material for the inner and outer slopes; the inner slope being usually the best material of the locality, carted in layers, or rammed, and the outer slope beyond the puddle core being the refuse of the borrow pit, dumped promiscuously outside the clay puddle wall. As to this latter, the purer the clay the more dangerous it becomes in case of a leak.

Think of an embankment 60 feet high, with a clay puddle core 20 feet thick at the bottom, an ordinary carted bank inside and a mass of rubbish outside. What is to save such a structure if the outer slope slips, or falls away from the core, either by disintegration or as the result of heavy rainfall, a water-spout, or any other cause?

All embankments which are intended to be impervious to water should be made of gravel, with just sufficient clay to bind it. Do not use it very wet, but dampen the material only sufficiently to make it pack, so that after it has been carted on in layers to a depth of several feet, the mass will yield and tremble under pressure as if made of India rubber. This is an indication of good puddling, and after such a bank has settled it will be water-tight and safe. Material designed to protect the outer slopes of a reservoir bank should always be of hard rock, such

as will not disintegrate by exposure to frost. Shales of all kinds should be excluded.

As to a masonry core the case is very different, provided the masonry be properly proportioned and well laid in hydraulic cement. It is good construction to make the mound on the outer slope of such a core, entirely of rock, if convenient, as only weight is necessary on that side. On the inside, however, just as much care should be taken in the make-up of the embankment as if there were no masonary core.

On all our canal systems in Pennsylvania we are so accustomed to the use of what we call gravel puddling that we are apt to think that every member of the profession understands just what is meant by it. I want to submit, with these notes, three samples.

Sample No. 1 is from a locality within five miles of the southern anthracite coal field, and is composed of small fragments of shale rock from the coal measures, with sufficient disintegrated shale, in the form of clay, to bind it. This material I have found to make an excellent water-tight embankment. The two Tumbling Run Reservoir mounds, feeder dams of the Schuylkill canal, one 48 and the other 60 feet high, are built of nearly the same material and have stood since 1835.

Sample No. 2 is disintegrated shale from the south side of the Blue Mountain range. It has about the same proportion of clay as has No. 1, but the shale is more nearly allied to the slates of the Lehigh region. It is good material for a bank. Our highest canal banks, through that section of country, never give any trouble. They are considered perfectly safe.

Sample No. 3 is from the city of Philadelphia, and is what is known as "Fairmount Gravel." It is composed of pebbles and sand from the disintegrated rocks of the whole valley, with a considerable percentage of clay, though not so large a proportion as in the other two samples. It is most excellent material for a water-tight bank, and is a good example of gravel puddling, as we understand it, with the *minimum* proportion of clay. I have never known of a failure of a reservoir embankment made of this material. The Fairmount basins, the East Park reservoir and others of the Philadelphia water supply, are built of this. It makes a good homogeneous bank, and does not require a core-wall of any kind, although the above-named works have inside puddle linings of clay on which the paving is laid.

CONDITION OF MATERIAL WHEN PLACED IN AN EMBANKMENT.

Whether the material of an embankment when being built should be entirely dry, damp, moderately wet, or saturated, depends very much upon its character. There can be no question as to saturation being entirely improper, except for a true clay puddle, the use of which is in

my view very questionable in any case, and for any purpose in the construction of a reservoir.

A sandy or gravelly loam, as it comes damp from the bank, needs little or no addition of water. The same is true of disintegrated shales. When the material is of sharp sand with a proper admixture of clay, or loam, reasonable dampness is not objectionable. It facilitates the packing of the material by rolling or tamping.

NECESSARY HEIGHT OF BANK ABOVE WATER LEVEL TO GUARD AGAINST INJURIOUS ACTION OF FROST.

For high reservoir embankments the practice should be to maintain the top of the bank at a height above the maximum water surface of the pool, at least 18 inches greater than the depth to which frost penetrates the ground in that section of country. In northern latitudes it is not unusual for frost to penetrate 4½ to 5 feet. Add 18 inches to this, and make the top of the bank 6 to 6½ feet above the water surface, and there will be no danger of injurious action of frost upon the bank.

For low embankments, especially those of water power canals, it is preferable to make the banks wider on top, and to depend upon the protection afforded by the extra width, rather than to raise them to an inconvenient height.

THE SLOPES OF THE EMBANKMENT.

The inner slope should be of 2 to 2½ feet base to 1 foot rise, and for impounding dams should be faced with a sufficient protection of stone not subject to disintegration, laid roughly as a wall, with joints at right angles to the face, for a depth of at least 6 feet below the water line. The stone should be of good size, but uncut, and laid dry in gravel or any coarse angular or pebbly material. Above the water line there should also be a wall of good material of larger stone, well laid, with spaces closely packed with gravel, and the face well pointed with cement. The top of the bank should in no case be less than 10 feet wide, and 16 feet would be better.

The outer slope of the bank may be carried up to the top of the mound with a slope of 1¼ feet base to 1 foot rise, keeping the face of the mound three feet or more back of the line of the finished slope, thus leaving the space for carrying up a rip-rap of stones of moderate size against it, with a slope of 1½ feet base to 1 foot rise. It will be readily understood that no stone liable to disintegration should be used in either the outer or the inner slope. The rip-rap may be carried up simultaneously with the puddled embankment, if the material is on hand and if it is convenient to do so.

THE WASTE WEIR OR SPILLWAY.

The waste weir or spillway should in all cases be built clear of the

mound, if it is possible to do so. If it can be excavated out of the solid rock of the hillside, and entirely clear of the mound, so much the better.

The width of the weir will depend upon the circumstances of each particular case—the drainage area to be impounded, the rainfall, floods, etc.

I recall a case where two reservoirs were built on the same stream in a mountain district. The upper one was 60 feet high, and had a drainage area of 5 square miles. Its waste weir was cut out of the rock of the side hill. The other reservoir, immediately below it, was 48 feet in height, and had a drainage area of 6 square miles. The waste weirs of both reservoirs were 20 feet wide and 6 feet below the top of the mound. A free and wide channel descended rapidly from the waste weir of the upper reservoir, while the channel leading from the lower waste weir, although of rapid fall, was not direct, and was at no point wider than the weir itself. On the occasion of a rainfall of 13 inches in less than 30 hours the waste weir of the upper reservoir passed the flood in safety, while the lower reservoir was destroyed, and a disastrous flood resulted in the valley below. The reservoir was rebuilt with a weir 40 feet wide, and its crest was placed one foot lower than before and provided with a removable flash-board to retain the water at its former level.

PIPES LAID THROUGH RESERVOIR EMBANKMENTS.

The precautions to be observed in laying pipes or flumes through canal or reservoir embankments demand the most careful consideration. The construction must be adapted to each particular locality; but, as a general rule of practice, pipe lines through high embankments should rest upon continuous foundations of cement masonry, and should be so thoroughly protected by ample cut-off walls that water cannot follow their outer sides. These cut-off walls should extend not less than 2 feet below the foundations, beyond the sides and above the top of the pipe wall. Accustomed as I am to building a homogeneous bank, I prefer to place the cut-offs as follows: One directly under the middle of the inner slope, one under the inner top line of the embankment, and the third under its outer top line. The head walls, or those of the gate chamber, should also have cut-offs. The pipes should be imbedded in cement masonry, or, better, in concrete, and should be covered with the same material to a depth of not less than one foot.

Pipe lines laid on piers of masonry, usually one under each bell-joint, are dangerous, especially in high embankments.

In one instance known to me, such an arrangement has remained safe for over 45 years, and it still remains. In another case, that of a reservoir built in 1834, with 41 feet of water and 47 feet height of

mound dam, the pipe line rested upon clay puddling with masonry piers 12 feet apart, center to center, each supporting a bell-joint. This form of support extended to a point in the embankment directly under the outer line of its top. Here was placed the head wall of a stone arched culvert, through which passed the water from the dam. This arrangement seemed to work well for 23 years, so long as the water was drawn through valves placed at the head of the pipe line.

The valves, however, proved troublesome, as it was necessary to work them from a trestle support reached by a bridge from the bank; and, there being no suspicion of any defect in the pipe, the line of pipe was extended through the culvert and imbedded in cement work, and valves were placed at their exit. This arrangement worked well for several years, until at length muddy water issuing from the culvert indicated that a leak had found its way apparently beneath the foundations of the pipes, which evidently had not been laid in cement masonry. This leak was at first very small, but slowly increased, and steps were taken to draw off the water and guard against accident to the embankment. The water surface had been reduced 13 feet, when suddenly, in the night, a mass of water, apparently 6 to 8 feet in diameter and shooting 20 feet in the air, poured out directly over the arch of the culvert. The outflow continued for a very short time, possibly two minutes, until the superincumbent bank, weighing many tons, broke down with a great crash and stopped the flow. The gap through the bank was about ten feet below the original top, and about six feet above the reduced water surface, and the destruction of the entire dam was thus averted. The culvert walls above the incased pipes, and the archway, were swept out, stones weighing half a ton being carried 500 feet down the valley. The bank evidently fell in consequence of a cavity formed above the pipes by the leakage acting upon it and gradually removing the puddling. Fortunately the pipe line remained intact upon its foundation. The bank was a homogeneous one, built of gravelly material, and without a core-wall.

At the time of the break there were 27 feet of water in the dam. If it had been a clay bank the destruction would have been complete. The work of repair revealed cracks in the pipes near the inlet and between the supporting piers.

In repairing this work, which came under my supervision, the pipes were imbedded in cement masonry, laid on a bed of concrete; and the valves were transferred to the position which they originally occupied in 1834, at the head of the pipes in the dam.

Only recently the case of an impounding reservoir dam, within 60 miles of Philadelphia, was brought to my notice. The dam was built about the year 1880. It is used for a city water supply, and is of heavy

rubble masonry, laid in cement and protected on the up-stream side by an embankment of gravel puddling, with a slope of 2 to 1. The dimensions are as follows: length of dam on top, about 200 feet; height from foundation, 65 feet; capacity, 80,000,000 gallons.

In the construction, the pipes were laid through the embankment on piers, one under each bell end.

A few weeks since, the water was drawn out of the dam for repairs. A small stream of muddy water awakened suspicion as to the condition of the 20-inch delivery main. An examination followed, and it was found that the narrow masonry piers had broken the pipes, crushing through the bottom, so that stones penetrated nearly to the middle of the pipe, reducing the discharge at least one-third. The great danger of using an impounding reservoir in that condition is apparent. The repairs were made by building a continuous wall under the pipes.

I need not refer to such details as the inlet tower, with sliding gates, next to the water in the reservoir, so that the water may be drawn from the chamber to permit of access to the valves at the head of the pipe line. What I want to emphasize is the necessity for solid masonry or concrete under pipe lines which pass through embankments of any considerable height, and the importance of placing the valves inside the dam, and not at the foot of the outer slope.

In the construction of wooden flumes, such as are common in connection with water-power and other canals, care must be taken to protect the foundation of the flume with at least three, or better, four, lines of sheet piling, and to extend these laterally a good distance beyond the sides of the flume.

By J. Waldo Smith, C. E.—What I have to say is based mainly upon experience gained while the works of the East Jersey Water Co., for Newark, N. J., were being constructed.

The Clinton and Oak Ridge dams are of earth, with concrete core-walls. They are about 45 feet high, 20 feet wide at top, with slopes of 2 to 1 on each side, a 16-feet berm on the water side and a 12-feet berm on the down-stream side.

The embankments were constructed in the usual way; spreading gravel in layers and rolling with two-ton grooved roller; except that gravel was spread in thinner layers than is often customary, not being over 4 inches thick, and making a compacted layer about 2½ inches thick.

At first the method of sprinkling and then rolling was followed, but it was found that better work could be done, and the material more perfectly compacted, by rolling thoroughly first, then sprinkling and rolling a short time longer, and giving a final wetting just before the

next layer was applied, thus leaving the surface in the best possible condition to receive it. The theory is that the air can better be forced out of the loose gravel, and the material better compacted when the latter is in a dry or naturally moist state, and that the subsequent addition of water still further settles and binds the whole mass.

Another advantage of their method of procedure, is, that the chance of getting an excess of water is greatly lessened.

If the loose material is sprinkled, especially if it is in about the right proportions for puddling, the chances are that too much water will be put on, the difficulty of rolling very much increased, and its effectiveness lessened.

In the case of a part of the Oak Ridge dam the material was in about the right proportion for puddling. Water had to be added very sparingly, and sometimes none was required. If the water had been added to the loose layer, the man with the watering cart, or hose, would have been almost certain to put on too much ; on rolling, the surface would have been reduced to a pasty condition, and when the excess of water dried or settled out. the material would have been left in a comparatively porous state. This frequently happens in filling trenches cut through banks already constructed.

In building earth dams there is often too much water and too little rolling. This need not be, for the rolling is but a small item in the expense. In the work referred to, where the gravel was applied in unusually thin layers, and where the rolling was consequently excessive as compared with ordinary cases, it cost only about 2 cents per cubic yard.

To sum up the foregoing in a few words, I may say :

1. Spread the material in thin layers.

2. Roll thoroughly. I should recommend rolling to an extent which many would consider excessive.

3. Sprinkle the hardened surface, not the loose gravel.

By John S. Hodgson.—The reference made in this discussion to the failure of the Dale Dike reservoir embankment near Sheffield, England, on March 11, 1864, was evidently based upon the belief that this catastrophe was due to the existence of two 18-inch cast-iron outlet pipes, laid side by side, and passing through the lower portion of the bank. As a matter of historical accuracy I think it unadvisable to allow this conclusion to pass without comment, although this view of the the case is, perhaps, a natural one if regard be had to the prominence given to this particular feature of construction in the Government Report, dated May 20, 1864, of the coroner's inquest held on the vic-

tims of the disaster. This inquest was attended by Mr. (now Sir) Robert Rawlinson and the late Mr. Nathaniel Beardmore, civil engineers, on behalf of the English Home Office, and the former gentleman took a leading part in the proceedings, besides publishing a memorandum and plans on reservoir construction in the Government Blue Book itself. One of these plans shows a cross-section of the bank and the outlet pipes, with a dotted indication of the probable settlement of the latter, while another shows what, in Mr. Rawlinson's opinion, ought to be the universal method of carrying off the water from impounding reservoirs, *i.e.*, by an outlet tunnel or culvert *in the solid ground*, as opposed to the carrying of pipes through an artificial embankment.

In the Sheffield case these pipes were not provided with "collars" for cutting off the direct flow of water along the outside of the pipes, but there seems little doubt, on the other hand, that the trench of clay puddle in which they were laid and by which they were surrounded was the most carefully executed feature of the whole work. The assumption that the pipes had settled in their puddle bed, and that the superincumbent puddle did not follow the pipes so as to fill the cavity thus produced, was incapable of proof in the ordinary way, owing to the enormous bulk of material left lying over their outlet ends after the burst. More than this, it was impartially urged at the inquest that, even if the pipes were bared and found to be ruptured, no proof of inherent failure (independent of the burst) would thereby be established, as no one could say whether such rupture was due to the original construction or to the destruction entailed by the burst. But so much stress had been laid upon the alleged settlement of the pipes that the directors of the water company sought for other means to arrive at a knowledge of the condition in which the pipes were left. They discussed the matter with Mr. George Eskholme, now a magistrate of the adjoining borough of Rotherham, from whom I have more than once heard the details of the disaster, and the result of his examination, made about four months afterwards. For the purpose of the examination he devised a small truck, with wheels to fit the periphery of the 18-inch pipes, and on this carriage he went through the whole length, examining each joint, and finally placing lighted candles at intervals along the pipes. His testimony is that not a single length of pipe had been "drawn" at its socket, even to the slightest extent, and that from the test by means of the line of candles, he is certain there was not so much as a quarter of an inch deviation, either vertically or laterally, in the entire length.

It will be readily apparent that if any settlement of the pipes had taken place, it would have been greatest in the middle of the line, not only because of the superior weight of the 95-feet bank at that point,

but also because the puddle trench, for a length of 16 feet along the line of pipes, was between 20 and 30 feet deep under them, while at the end of the pipes there was merely a thickness of 18 inches of puddle between the pipes and the undisturbed solid ground of the valley.

No very diligent search is needed, in other directions, to find a far more obvious and probable cause for this disaster. The embankment was inherently bad in construction, formed of "tips" varying from 3 to 6 feet in thickness, and of materials so unsuitable that Mr. Rawlinson himself summarized his conclusions thereon in these words: "From the mode of tipping the wagons, and from the character of the materials tipped, I have no hesitation in coming to the conclusion that the substance of that bank is as porous as a sieve." He gave utterance to the same view in another form by saying that "if the inner part of the embankment could have kept the water from the puddle we should probably never have heard of the accident." There were also faulty items of design, notably in the too restricted top width of the embankment and in the insufficient thickness of the puddle wall at its base, to which I need not further refer.

THE PRESIDENT.—During a conversation with Mr. Jackson, City Engineer of Boston, reference was made to a report by the late James B. Francis, which bore so directly upon the subject which we are now considering that Mr. Jackson suggested incorporating it in the discussion. Such incorporation is especially appropriate at this time when we have just listened to the memoirs recounting many of Mr. Francis' works. Mr. Francis was continually called upon to present reports upon important undertakings, and the present one, with its brief but lucid statements, forms a good illustration of their character.

HENRY M. WIGHTMAN, ESQ., City Engineer, Boston.

DEAR SIR:—In accordance with your request I have examined the preliminary design for Dam No. 4 on Sudbury River, and I beg leave to submit the following remarks on the same:

The dam is designed to retain the water in the reservoir to a height of about 45 feet at its deepest part. By the plan submitted the dam consists of an embankment extending 6 feet above the level of high water, 20 feet wide on the top, with a slope on the water side of 1 foot vertical to $1\frac{3}{4}$ feet horizontal, and on the other side of 1 foot vertical to 2 feet horizontal. In the middle of the embankment is a wall of stone masonry* 3 feet thick at the top, 8 feet thick at the level of the natural

* The core-wall was actually built of concrete, plastered with Portland cement on the face next the reservoir.—W. J., September 21, 1893.

surface of the ground, where the water will be 45 feet deep, and of the same thickness to the rock at whatever depth it may be found.

I assume that the embankment on the water side of the wall will be of selected material suitable for the purpose, also that the wall will be plastered on the face next the reservoir, and that the embankment on the outer side of the wall will be of porous material to allow of the free escape of any leakage that may occur.

The stability of this construction I consider to depend mainly on the mass of earth in the embankment on the down-stream side of the wall. The tightness depends on the quality and compactness of the material forming the part of the embankment between the wall and the water and the wall itself. The lower part of the wall, between the base of the artificial embankment and the rock, will cut off the percolation which would otherwise probably take place through the natural ground, between the base of the embankment and the rock.

In estimating the stability of the dam it will be prudent to assume that the wall sustains the full hydrostatic pressure of the water in the reservoir. The wall, as designed, is obviously incompetent to sustain this pressure without the support of the outer part of the embankment to a greater extent than its natural pressure against the wall, and to be sufficient without that support it must be two or three times as thick as is proposed. Under these circumstances I think it would be proper to assume that the strength of the dam must be sufficient to withstand the pressure without the wall, and that the function of the wall is simply to insure the tightness of the dam.

With the proposed height of the embankment of 6 feet above the water in the reservoir when full, with a width of 20 feet on top and with a slope of $1\frac{3}{4}$ to 1 on the inside and 2 to 1 on the outside as proposed in the design submitted, I think there would be ample strength, but in view of the natural tendency of such an embankment to weaken from frost and other causes, I should recommend that the slope be made somewhat flatter on the outside, say not less than $2\frac{1}{2}$ to 1.

As to the thickness of the center wall, I do not see that any material advantage would be gained by making it any thicker than is proposed, unless it should be so much thicker as to be incapable of yielding to the full hydrostatic pressure of a full reservoir, which would entirely change the character of the structure, and I do not suggest any change in this respect.

The pressure of the water on the up-stream face of the wall will be transmitted, in part, to the earth on the back of the wall, which I should expect would be compressed slightly, and the wall and part of the embankment in front of it would follow to the same extent, which if it exceeded in amount the elasticity of the masonry would produce minute

cracks in the wall. The amount of this compression and of the consequent cracking of the wall, if any, will depend much upon the solidity of the embankment, and, with the care that I have no doubt will be taken in this respect, I think it will be of very small amount, and that the leakage, if any, on this account will be extremely small, and with porous material in this part of the embankment can have no injurious effect on the safety of the dam.

Very respectfully,

James B. Francis.

Lowell, Mass., August 18, 1881.

The President.—As our City Engineer has during the past twenty years had much experience with reservoir construction, and as he was therefore in position to contribute much to the instruction of the evening he was urged to be present, but other engagements have prevented.

In conversation on this and kindred topics he repeated one of the late Mr. Wightman's anecdotes of how an elm tree, growing at the foot of a reservoir bank, caused its ruin. A root, searching for moisture, penetrated under the bank and afterward decayed; and a vein of water followed in the cavity left by the decaying root. The occurrence and the anecdote were of so long ago that I have forgotten the location and the exact circumstances.

Our member, Mr. Tidd, had still another kind of foe to contend with, and here we can give the local habitation and the name. At the reservoir of the Lewiston (Me.) water-works a woodchuck dug his hole 16 feet back into a firmly compacted bank of tenacious material. He then paused, and, reflecting on Mr. Tidd's popularity and on his many friends, concluded it would be imprudent to carry any further the attempt to injure his reputation.

Mr. Herschel has expressed the opinion that the plastering of sheet piling with clay, in order to preserve it, is an expedient of little value.

My own experience in a few instances has indicated that clay is remarkably useful for this purpose. I well recall a flume forty years old, which had been packed in about six inches of clay, and which, when torn out, was found in remarkably good preservation, the outside of the planking of the sides and top being fairly bright and sound, and I recollect with equal distinctness another flume, scarcely a quarter of a mile distant upon the same canal and in similar ground, but with no clay packing and with loose damp sand lying against the wood-work. This latter flume, although continuously filled with water, had scarcely an inch in thickness of sound wood left. The outside was very badly

softened and decayed, although the flume was only 25 feet distant from the canal and was 8 feet below its surface. The second flume, although only about sixteen years old, was far more decayed than the one forty years old which had been packed in clay. In both cases the wood was Northern pine.

The following letter is from a mill-wright of large experience and of unusual intelligence. Knowing that his work in connection with the water power at Lawrence and elsewhere had given him excellent opportunities to study this question, I wrote asking him to give the Society the benefit of his experience.

LAWRENCE, MASS., October 13, 1893.

JOHN R. FREEMAN, ESQ., President, Boston Society of Civil Engineers.

DEAR SIR :—During the past twenty years I have seen many cases where piling was covered partly with sand and partly with clay, both white and blue, and in every case where the clay was well packed against the wood it exerted a preservative effect upon it.

In 1882 the head of the Spicket penstock at Lawrence, built thirty-four years before, was repaired, and it was found that wherever the piling had been covered with clay it remained sound, but that where it was in contact with sand it had decayed. The piling was put in when the canal was built.

A similar condition of things was found at the time of the repairs to the piling at the west side of the upper lock at the lower end of the Northern canal in Lawrence; at the tail race of the Washington Mills, where I helped to take out some of the old coffer-dam which had been put in forty years before; in relaying the canal wall along the front of the lower Pacific Mills in 1875; and last summer while repairing the waste weir at the lower end of the Northern canal in Lawrence.

Some three years ago, while driving piling at South Gardiner, Maine, we found a maple stump, and, upon digging it out, the part which was in the gravel was found to be thoroughly decayed, but the roots in the blue clay were sound and well preserved.

All my experience shows that two solid inches of good clay in contact with wood will preserve it indefinitely; but I believe that in using clay to preserve wood, too much water is generally used, for I have seen cases where the clay around piling appeared to have shrunk away from the wood, letting the sand fall in and permitting the wood to decay. I try to have the clay just moist enough to pack well, using a driver such as we use in packing cement concrete. It then shrinks very little and leaves no space for sand or air to come between the clay and the wood.

Yours,

CHARLES C. CAMPBELL.

A NEW SYSTEM OF BLOCK SIGNALS.

By Arthur A. Skeels, Member of Civil Engineers' Club of Cleveland.

[Read February 13, 1894.]

During the six months ending December 31, 1893, there were, according to *The Railroad Gazette*, 1,112 serious railway accidents. In these accidents 402 persons were killed and 1,270 seriously injured, and of these many suffered torture.

It would be impossible to estimate the enormous financial loss resulting from these and from the hundreds of lesser accidents which occurred during this time. One wreck alone, it was said, cost the railroad company $500,000.

The World's Fair probably had some effect in swelling the list of accidents, particularly during October, and yet November and December came within five accidents of having one-third of the whole number.

The above, then, is at most only a slight exaggeration of what has been going on for years, and, according to present appearances, it is likely to continue for years to come.

We are so thoroughly used to this every-day matter of railway mishaps that it requires a great one to attract our attention. During the three years and more of my membership in this club I do not remember to have heard a single word about a possible relief from this state of affairs, and, judging from the contents of The Journal of the Association of Engineering Societies, I take it that other societies have kept as clear of this subject as we have.

But why should this be so? We, who get into such heated discussions over a new process of manufacture, or a new method of construction, or what not, whereby comparatively small sums may be saved, why should we almost or quite neglect to consider means for diminishing this wholesale destruction of life and property?

Are we not equal to the task? We, who "harness the lightning and make it haul our cars through our streets;" we, who "talk with our friends over a thousand miles of wire;" we, who "can construct a machine to pull us a mile in thirty-two seconds;" we, the people of America, in the light of this nineteenth century, are we to stand idly by while serious railway accidents occur at the rate of 185 per month?

The people suffer death and injury in these mishaps; the people pay, indirectly, for this destruction of property, and we are the people.

There is before us an unsolved problem; to devise a system of signals which will do its work well, and yet be *cheap* enough to find universal adoption.

During the six months to which I referred, 46 per cent. of the accidents, 61 per cent. of the deaths and 54 per cent. of the injuries were caused by collisions. I wish to present to-night for your consideration a cheap signal system which will prevent collisions.

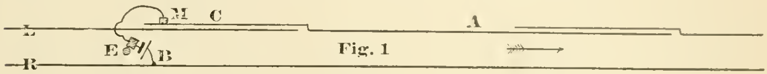


Fig. 1

Let Fig. 1 represent one of the tracks of a double-track railway, with trains running in the direction of the arrow. One line of rails, as *R*, is made electrically continuous by short track wires passing around the joints. The other line *L* has the joints wired in the same way, but is divided into sections of any desired length. These sections are insulated from each other and from the other line of rails.

The overlapping lines *C* represent contact strips placed just outside of the rails and connected with the sections as shown.

On the locomotive is a battery, *B*, Fig. 1, one pole of which is connected to the continuous line of rails *R*, while the other pole is connected with a metallic brush *M*, which rubs along the contact strip *C* as the engine passes. On the circuit within the locomotive is an electric bell *E*. In the position shown there is evidently no circuit, and hence no ringing of the bell, nor will there be as the engine proceeds past the succeeding contacts, provided the track ahead be clear. But if there is a train in the section ahead, as at *A*, a circuit will be formed through the wheels of that train, and the bell *E* on our engine will ring as soon as the brush *M* touches the contact strip *C*. This strip is made of such length that the engineer can bring his train to a stop before reaching the beginning of the section ahead. He then waits a certain time, and if the bell continues to ring he proceeds under control, or, if the absolute block system is in force, he waits untill the bell stops ringing.

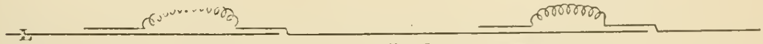


Fig. 2

To avoid the necessity of a long contact strip, it may be divided into two parts connected with a wire, as shown by Fig. 2. Each contact will then need to be only long enough to ring the bell distinctly as the engine passes at its highest speed.

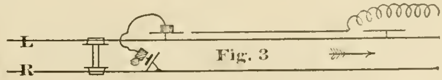


Fig. 3

To avoid the danger which would arise if the bell or battery should get out of order, we may arrange each contact strip between two shorter ones, as in Fig. 3. The latter are connected directly with rail *L*, as

shown, and thus, through the locomotive itself, with rail *R*. Evidently the circuit will be completed through these shorter contacts, and the bell will ring while the brush is in contact with either of them, whether the section ahead be clear or not. The safety signal then will be two rings, with an interval between, while the danger signal will be three rings so close together as to sound like one long ring. This makes the signal active both for safety and for danger, while if the apparatus is out of order that fact is indicated by the silence of the bell.

Since any connection across the track will ring the bell of an approaching train, switches can easily be so arranged that when opened they will short-circuit the two lines of rails and give the danger signal.

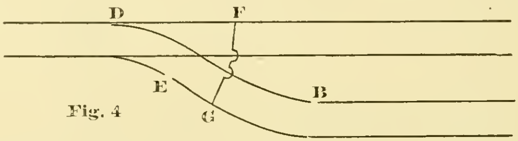


Fig. 4

By inspection of Fig. 4, we can see that with one connection *F G* and two insulation joints *B* and *E* we can so arrange a side track that if a car be standing too near the main track, that is, nearer than the point *B*, it will short-circuit the main track and give the danger signal.

The system may be applied to a single-track road by doubling the contacts, as shown in Fig. 5. Of course it is not necessary to put any contacts on the inner sides of the rails.

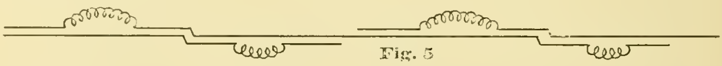


Fig. 5

Evidently also this system may be applied at isolated points to protect places of special danger, such as yards and crossings, tunnels and drawbridges, etc.

The mechanical details are comparatively few and simple. Everything in connection with the track wiring has been thoroughly tried for years, in essentially the form here shown. Of course the metal contact strips must be kept clean, but this can be done by special cleaning brushes placed in front of the contact brush.

I think that unless an absolute block system is required an open-circuit battery can be used. This would reduce to a minimum the expense and trouble due to the battery.

The adoption of this system would not interfere with existing non-electric signals, and it would cause no confusion.

The great merit of this system lies in its simplicity and its cheapness.

DISCUSSION.

Mr. Wm. H. Searles.—Would not this system enable train robbers to hold up a train by putting a loose rail across a track?

Mr. Skeels.—They could do that with the ordinary electric block system as it is used now.

Mr. Blunt.—Would not the bell in Figs. 1 and 2 be made to ring by the presence of the engine on the section behind? Would not the circuit be closed by the engine?

Mr. Skeels.—No. There can be no connection, because the engine itself is on the rear section, while the brush is on the forward section, and does not touch the rear section, on which the engine or train is. If there is nothing joining the two rails of the forward section, as at *A* (Fig. 1), the circuit cannot be completed, for the circuit is broken through the joint at *C*. If two trains are too close together the bell on the rear train alone would ring, and not that on the forward train. The engineer of the rear train would want to know that the section ahead was occupied; but it, of course, would not do to stop the forward train when another train was coming behind. However, there is one objection, viz.: If the continuity of the track were broken the engineer would not know it.

Mr. S. T. Todd.—I should think that if the continuity of the track were broken the safety signal would refuse to ring, and this of itself would indicate danger. On a rainy day, would there not be enough leakage through the wet rails to ring the bell?

Mr. Skeels.—The safety signal would ring, even if continuity were broken, because these contacts are connected directly with the rails. The wetness of the rails would not affect the ringing of the bell.

Mr. E. P. Roberts.—Leakage gives no great trouble with any of these systems. A dry battery can be used in the cab if desired.

THE CONTRIBUTION BOX.

Members of the associated societies, and other persons, are invited to send to the Secretary, for this department of the JOURNAL, such matters of general interest as may come to their notice.

St. Louis Boulevards in the Business District.

There has recently been a movement in St. Louis to bring about the widening of streets in the business portion of the city. For this purpose the Society of Architects and the Society of Engineers have appointed a joint committee of five from members of each society, and this joint committee has taken steps to bring together representatives of other important associations in the city to form a committee of fifty. Attention has been called to the narrowness of the streets by the location of the new Union Depot at Eighteenth and Market Streets, which although one of the largest stations in the world, if not the largest, is surrounded by streets not over 60 feet wide. If the plan outlined by some of the gentlemen interested is ultimately carried out it will add greatly to the beauty and prosperity of the city.

The plan includes a grand plaza in front of the new Union Depot and four boulevards; one extending eastward to Twelfth Street, which is now 200 feet wide, passing in front of the new City Hall, now nearing completion; one northward for several blocks; one westward to connect with the parks, and one southward to the southern and southwestern portions of the city.

Property along these streets could now be condemned, and benefits assessed nearly equal to the total damage; and the committees which have been appointed by the engineers and architects are receiving very substantial encouragement from all leading citizens. It seems that such a movement as this should very properly originate with the engineers and architects, and that such action is one of the legitimate functions of these professional organizations.

Smoke Abatement in St. Louis.

Mr. Robert E. McMath, of St. Louis, Mo., sends copies of City Ordinances Nos. 17,049 and 17,050 respecting smoke abatement, and some account of their working.

Ordinance No. 17,049 declares the emission of "dense black or thick gray" smoke to be a nuisance, and provides a fine of fifty dollars for each commission of such nuisance, each day during which the nuisance continues being counted a separate offense.

Ordinance No. 17,050 provides that the President of the Board of Public Improvement shall, with the approval of the Mayor, appoint not more than three Inspectors to carry out the provisions of the ordinance, and a Commission of three competent and disinterested persons, to investigate and report to the Board within four months with regard to cases where it may appear that smoke suppression

cannot reasonably be enforced; the report of the Commission, when approved by the Board and by the Mayor, to constitute standing instructions to the inspectors. The Commission is also to test smoke-preventing devices and alleged smokeless fuels, and to report to the Board with regard to the same. The Mayor can dissolve the Commission when, in his judgment, no further call exists for its services.

Both ordinances were approved February 17, 1893, and went into effect on August 17th, but active steps for their enforcement were first taken a month later.

A recent canvass of the city showed that up to February 1st, 268 out of 872 establishments, or 29.5 per cent., had installed smoke-preventing devices of various types, 115 using simple steam jets.

The larger establishments, however, are co-operating more effectually with the anti-smoke movement. Thus, in the Central District, 391 boilers out of 888, or 44 per cent., are fitted with smoke-abating devices.

Silt in Underdrains.

The importance and the difficulty of laying sub-drains so as to admit water and yet exclude all solid particles, has been illustrated by recent experience at the filtration beds of the Boston Water Works, where Pegan Brook enters Lake Cochituate. A few short drains were laid at depths of about 8 feet in the sand through which water is filtered. They were made of 8-inch Akron vitrified clay pipe. Some of the joints fitted inexactly, the ends of the pipes not being exactly circular or of exact size, so that in some places the hub ends had to be chipped off to make the joints, and in other places there was an unnecessarily wide space between the outside of the hub and the interior of the bell. To prevent anything but water from getting into the pipe before the sand should have had time to become thoroughly compacted around it, canvas was carefully wrapped around the pipe when it was laid. After water was admitted upon the beds it was soon found that some sand and rootlets had got into the pipes, and upon digging down and repairing some parts of the drains it was found that a very few months had sufficed to rot the canvas, so that there was practically nothing left of it. On February 22, 1894, when there was a foot or two of water on one of the beds, a breach, evidently due to the defects of the drain, was made in the surrounding embankment at the place where a drain passed under it. Water burst forth from the ground where the drain was outside of the embankment, and rapidly undermined the bank, so that by the time the water had all run off from the bed, a portion of the embankment, 25 feet long, was gone and several hundred cubic yards of material had been washed out.

FRED. BROOKS.

The Government Timber Tests.

Professor J. B. Johnson, in charge of the United States Government Timber Tests, has issued a timely circular calling upon those interested in the work to communicate with their Congressmen and with Senators Roach and Proctor, urging the importance of the work and the need of liberal appropriations for its continuance and extension. The Senators named constitute a sub-committee of the Committee on Agriculture and Forestry, charged with the consideration of a bill making an appropriation for the work.

During the first year of the work, 1890, a small appropriation was made. The second year $2,000 were appropriated. In 1893 a bill appropriating $40,000 was introduced, but failed to pass, and an addition of $12,000 was made to the Department bill as a direct result of the demands made upon Congressmen by those interested in the work. It is believed that if a liberal sum is now appropriated an additional testing laboratory may be established on the Pacific Coast for the purpose of testing the timbers of that region.

Mr. Morison's Practice in Rail Joints.

On the Memphis Bridge, in order to prevent wear and lost motion in the rail joints, Mr. Morison drilled the angle bars with circular holes tightly fitting the bolts, while the circular holes in the webs of the rails are about one-quarter of an inch larger, his object being to render the two fish plates, with their bolts, as nearly as possible a single member, so that when sliding friction between the rail and that member takes place, as it must under changes of temperature, such friction shall be confined to the surface between the rail and this member, and shall not extend to the parts of the member itself.

Mr. Morison writes the Box that he has just walked over this track, which has now been in use for nearly two years, and that the bolts put in under that system all seem to be tight, while others put in since then and in the usual way, are almost invariably loose.

The Stone Mountain and Lithonia Granite Quarries, Ga.

Messrs. Venable Bros., Atlanta, Ga., have issued a circular pamphlet descriptive of their quarries, and illustrated with very interesting photographs of those quarries and of the work in them. The frontispiece is a striking view of Stone Mountain itself, which appears to be a great disk with gently sloping sides, looking as though unlimited glaciers had descended from the top of the hill, striating the sides as they went down.

This mountain, it is claimed, contains the largest deposit of merchantable granite in the world. The property contains some 200 acres, of which 563 acres are granite. The mountain measures seven miles in circumference at the base, and is estimated to contain over 7½ billion cubic feet ot exposed granite above the surface level of the plain.

Wooden Chimneys for Roundhouses.

Mr. William H. Searles sends us from Cleveland a clipping from a daily paper, stating that in Maine a number of locomotive roundhouses have been furnished with chimneys built of wood, sprinkled with sand, which replace the sheet iron funnel with flaring bottom suspended over each locomotive stall. It is claimed that the smoke preserves these wooden chimneys, and we presume that they are not found liable to ignition.

Some of the Boston members should be able to give further particulars about this, and the Box will be glad to hear from them.

Loss by Seepage from Irrigation Ditches.

The State Agricultural College at Fort Collins, Colorado, issues a bulletin in which, among other things, attention is called to the loss by seepage from ditches. At several points in Colorado the farmers, in order to avoid this loss and the resulting difficulty with their neighbors, have been constructing their lateral ditches of sewer pipe, and the College itself is constructing such a line of 15-inch sewer pipe 4,000 feet long, with gathering galleries of smaller pipe laid without cement.

Irrigation in Canada.

The same bulletin informs us of a visit by Mr. Dennis, Inspector of Irrigation in Canada, to the State College, for the purpose of gaining information which will enable the Dominion to profit by both the successes and the failures made in Colorado.

A Proposition for a National Public Works Convention.

Mr. M. J. Murphy, Street Commissioner of St. Louis, has issued to the Boards of Public Improvements throughout the country a letter soliciting an expression of opinion with respect to the feasibility and desirability of holding a National Convention of members of such bodies, with a view to an interchange of ideas and information relative to the government of cities and to the methods of municipal management with regard to public works.

In these days of national and international conventions there would seem to be no question as to the feasibility of such a plan, and its eminent desirability appears no less evident. To-day, as never before, we are realizing the force of the old prophecy that many shall run to and fro and knowledge shall be increased, and certainly there is no field of activity in which such interchange of ideas would be more likely to be productive of beneficient and far-reaching results.

The importance of the municipal engineer is becoming daily more pronounced, and the pages of our JOURNAL are largely occupied with matters concerning him, arguing that he is an influential factor in the ranks of our societies. The Box therefore, cordially seconds Commissioner Murphy's invitation by asking our readers for the expression of their views in these colums.

THE LIBRARY.

It is proposed to notice briefly in this department of the JOURNAL such engineering publications as may find their way to our shelves.

Publishers are requested, in sending works for review, to state the prices of same.

Sanitary Improvements for the City and Port of Santos, Brazil. Prepared by E. A Fuertes, Engineer under contract with the Government of São Paulo; Rudolph Hering and J. H. Fuertes, Consulting Engineers. New York, 1894. 146 pages, 12 by 9 inches, in large type, with numerous appendices. Printed for private distribution.

This report embraces the results of an investigation of the sanitary conditions of the sea-port town of Santos, in the State of São Paulo, Brazil, having an estimated population of about 27,000, and situated upon an island about three miles back from the Atlantic coast, and some 300 miles W. S. W. of Rio de Janeiro. The island is a low marshy plain crossed by a range of granite hills, and the sanitary condition of the town has been anything but admirable. The water supply and the sewerage system were both found inadequate, and it is not strange that the town has been frequently visited by smallpox, yellow fever and other scourges.

The report advises dilution rather than artificial purification of the sewage, and recommends the use of the separate system, with an outfall into deep swiftly running water. The Shone ejector system is recommended for one of the districts, in which it would be impracticable to deliver the sewage by gravity to a point where the pumping station would be economically available for the other two districts.

Water Supply for Irrigation. By Frederick Haynes Newell. Extract from the thirteenth annual report of the Director of the U. S. Geological Survey, Washington. Government Printing Office, 1894. 99 pages, 12 by 7½ inches.

This report is the fourth of a series relating to the hydrography of the arid regions. The area of the land surface of the United States west of the 100th meridian is nearly 1,400,000 sq. miles, or 610,000,000 acres, of which only about 3,600,000 acres, or less than six-tenths of one per cent., have been provided with a water supply sufficient for the raising of crops, and it is believed that probably not more than three per cent. can well be brought under irrigation.

The report contains valuable and interesting diagrams showing the discharges of some of the principal western rivers, their drainage basins and depth of run-off, their periodic and nonperiodic oscillations, and the distribution of the mean monthly precipitation at sixteen stations in the Western States. The Missouri, Yellowstone and Platte River basins are each handled at considerable length, and each illustrated by a map showing in colors the areas occupied by irrigated, pasture, firewood and timber lands respectively.

City Engineer of the City of Omaha, ANNUAL REPORT OF THE —. January 1, 1894. 77 pages, 9 by 5½ inches.

After describing the condition of the city sewers and water-works. Mr. Andrew Rosewater, the City Engineer, proceeds to consider the question of the construction

of a canal for the purpose of bringing water-power to the city with a view to rendering it a great manufacturing center. A project of this kind was under consideration by a private company, which, however, after expending considerable money for surveys and for engineering advice, suddenly abandoned the project as futile in view of the financial stringency, and tendered the results of its surveys to the city free of cost, hoping that the enterprise it had developed would be undertaken as a municipal operation for the general good. The basins of the Missouri, Elkhorn and Platte Rivers are considered, the latter at considerable length, and, in conclusion the engineer finds that, with the existing conditions at Omaha, water-power is cheaper than steam-power for the purpose, and recommends the installation of large central stations and the use of electricity for lighting and railway purposes, and of compressed air for general distribution of power.

The report presents a map of the proposed Platte River Canal, and four excellent city maps showing respectively the water-works, sewerage, paving and lighting systems. The paving map shows about 20 miles of asphalt, 23 of stone, 10 of brick and 23 of wood paving.

St. Louis River, REPORT OF THE WATER SUPPLY, SOURCE AND UPPER WATERS OF THE —. By Ambrose E. Lehman, C.E., Philadelphia, 1894. 22 pages.

A report in pamphlet form to the St. Louis River Water Power Co., of Philadelphia, giving an account of a hasty exploration of the river in question, which rises in Northern Minnesota, the object of the exploration being to determine the source of the river and the character of the water supply, and to ascertain to what extent such waters can be impounded during the wet months of the year in order to furnish a sufficient and constant supply to the lower river during the dry seasons.

The report represents the country embraced within the water-shed of the river as having an area of some 4,000 square miles, as being chiefly a great swamp, of little use, except as a gathering ground for the purpose in view. Mr. Lehman believes that the falls of 450 feet within 20 miles of Duluth can, at a comparatively trifling cost, be harnessed to mechanism that will provide sufficient electric force to supply power, light, transportation, etc., to Duluth and Superior or (if the plan of carrying the Niagara power to Albany should prove feasible) to St. Paul and Minneapolis. The report closes with a glowing prophecy by one Capt. Alexander MacDougal respecting the future of the head of the lakes, and gives a sketch map of the water-shed of the St. Louis River.

Society Proceedings.

THE SELECTED PAPERS OF THE RENSSELAER SOCIETY OF ENGINEERS, which, owing to unavoidable difficulties and delays, has not been issued for the past two years, now appears with Vol. II, No. 3, under date of January, 1894. It contains four valuable papers, namely: "On the Theory of the Masonry Arch," by William H. Burr; "Notes on Railway Earthwork," by Prof. W. G. Raymond; "Determination of the Size of a Supply Main for the Galveston Water Supply," by Mr. Wynkoop Kiersted, whose paper on "Water Supplies" graced our January number, and on "Natural Asphaltum and its Compounds," by Mr. J. W. Howard.

PROCEEDINGS OF THE ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA, which, like our journal, is printed in Philadelphia, resembles it also in this, that it is coming up with its arrears of publication. The March number reaches the Box

while ours is still in course of preparation. It is, however, in comparison, quite a tiny production, the number in question containing only eight pages, exclusive of copy and advertisements; and the members of our societies, when they reflect that the price of this little monthly is 75 cents per copy, can realize the advantages conferred by the larger co-operation into which they have entered.

PROCEEDINGS OF THE ENGINEERS' CLUB OF PHILADELPHIA. The Publication Committee of this Club has adopted a new system of dating its quarterly proceedings. The number which, under the former system, would have been dated April, 1894, is just at hand, bearing the date, January—March, 1894. It is essentially a bridge number, containing, as it does, articles on the new plate-girder bridge of the Philadelphia and Reading Railroad over the Schuylkill, by Mr. W. B. Riegner; on Current Practice in the Design of Plate Girders, by Prof. Edgar Marburg, and on the Old Viaduct Bridge over the Conemaugh, by J. Chester Wilson. There is also an interesting paper by Mr. Edward K. Landis on the Magnetic Concentration of Iron Ores, and Mr. Frederick Lewis takes occasion to criticise severely the new building law recently enacted by the Legislature of Pennsylvania and governing cities of the first class in that Commonwealth.

The quarterly numbers of these Proceedings approximately equal those of our monthly Journal in size. Their price is 75 cents each, or $2 per volume of four numbers.

PROCEEDINGS OF THE ALABAMA INDUSTRIAL AND SCIENTIFIC SOCIETY. University Post Office, Alabama. Vol. III, 1893.

This annual volume of 62 pages comprises the proceedings of the spring and autumn meetings, with papers on Coke, by Richard Thomas, on the Proper Grading of Southern Pig-iron, by A. E. Barton; and two papers on the Generation of Steam by the Use of Waste Gases, one of these, by Mr. J. Wideman Murray, relating to Blast-furnace Gases; and the other, an illustrated paper of 21 pages, by Erskine Ramsay, referring to the Waste Heat and Gases of Coke Ovens.

TRANSACTIONS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS. Vol. XXXI, No. 3. March, 1894.

This number opens with a very satisfactory paper, by Mr. C. R. Grimm, on the iron framework to surmount the tower of the new City Hall at Philadelphia. The paper is well illustrated. Incidentally, it gives a record of experiments to ascertain the effect of alternating heat and cold in causing deflections of the tower.

In this number are printed also Mr. Robert Cartwright's paper on the New Electric Station at Rochester; an Account of the Lining of a Waterworks Tunnel with Concrete, by Mr. Desmond Fitz Gerald; and a short retrospective paper on Spirals, by A. S. C. Würtele, giving tables for use on steam and on street railroads. Mr. L. L. Tribus describes the driven wells of the Plainfield Water Supply System. There are two papers on Bridge Piers, one by Mr. Howard C. Kelley, on the Removal and Reconstruction of a Defective Pivot Pier; and one by Mr. Martin L. Byers, on the Renewal of the Channel Pier of a Railway Bridge over the Scioto River.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881.

VOL. XIII. APRIL, 1894. NO. 4.

NOTES ON WATER POWER EQUIPMENT.

BY A. W. HUNKING, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read November 15 and December 20, 1893.]

INTRODUCTORY.

IN the United States Census for 1880, Vols. XVI and XVII are devoted to the statistics of water power, and it is there stated that at that time there were in use in this country some 55,000 water wheels, or about 13 per cent. more than in 1870. It is also estimated that the amount of water power developed at the time of the investigations represented only about 5 per cent. of the total available power in the country.

Since 1880 great advances have been made in the transmission of power over electric wires, and the result has been a great impetus to the utilization of water power. Particularly is this true of the small and isolated towns and villages in many of the Western States, where, owing to the high cost of coal and of transportation, a public gas supply would not have been installed for many years to come, if ever, but where electric light and power may be economically produced on a small scale by water power.

Again, water power has of late been eagerly sought for the manufacture of paper and pulp. The latter business requires for its successful prosecution immense quantities of power, coupled with certain conditions of speed, and many old mills have been forced to renovate their methods and appliances.

We may therefore safely estimate that the increase in the number of water wheels since 1880 will far exceed the 13 per cent. of the previous decade; and the writer will hazard the opinion that a census taken at the present time would show something like 70,000 water wheels in use throughout the United States.

There would be little difficulty in proving that an estimate of 2,000 wheels would more than cover the entire aggregate turbine equipment now in use on the large and well-known powers, including Lowell, Lawrence, Manchester, Bellows Falls, Turner's Falls, Holyoke and Lewiston in New England; Cohoes, Watertown and Niagara Falls in New York; Appleton, Wisconsin, and adjoining towns on Fox River;* Minneapolis, Minn.; Great Falls, Montana; Spokane, Washington; Oregon City, Oregon;† Richmond, Virginia, and Augusta and Columbus, Georgia. The other 68,000 of our assumed 70,000 wheels must then be located on the smaller and less widely-known powers found throughout the country and varying in magnitude from 2,500 to 500 horse-power, and from that to the most insignificant country mill privilege. Many of these powers have falls of only from 8 to 10 feet, and the mills are often located in groups having a common interest in the flow of the stream. Powers of 500 horse-power and less are usually in charge of a local millwright, while very large powers are usually in charge of a resident engineer. Hence the water-power engineer finds his occupation chiefly in solving the problem of developing and re-arranging isolated powers of moderate size.

The engineer will have occasion to deal with all sorts of water wheels (as well as with all sorts of clients); but in what follows the writer will refer especially to what has been designated as the purely American type of water wheel; that is, a wheel having a mixed flow or an inward and downward discharge, as in the Swain, Hercules, Victor and some other wheels.

The method of testing wheels employed at the Holyoke testing flume and inaugrated a few years ago by Mr. Clemens Herschel, mem-

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* Fox River deserves more than a passing notice. Lake Winnebago, in Wisconsin, with its 106 square miles of water surface, is its source. It flows northerly about 28 miles and falls about 175 feet in its course into Lake Michigan. Every foot of that fall is now developed in units varying from 6 to 22 feet, and probably 450 water wheels are turned by it. When arrangements shall have been made for the proper management of the lake outlet (as was done for so many years for mill purposes at the outlet of Lake Winnipiseogee, N. H., at the head of Merrimack River) the Fox River will rank as one of the largest and most reliable water powers in this country.

† At Oregon City wheels carrying electrical armatures at the tops of their vertical shafts are now being installed.

ber of this Society, has had a widespread effect among mill owners; most of whom are now awakening to the importance of using wheels of high efficiency and durability.

Progressive manufacturers of water wheels too, urged on by close competition, have been at great expense to test carefully, and to revise when necessary, all patterns of wheels which they put upon the market. They have striven also to reduce the cost of the wheel and its appurtenances without impairing its efficiency or durability, until now the cost per horse-power of the iron work pertaining to a complete water-power equipment is less than one-fourth of that of the old-time equipment with Boyden wheels.

CONSIDERATIONS AFFECTING THE SELECTION OF A TURBINE.

A vital point in the matter of water-power equipment is the commercial value of a high percentage of useful effect.

Reliable tests of water wheels show that at their best point of efficiency they vary from 80 to 85 per cent., while a few may reach 86 or even 88 per cent.; but it may be laid down as a rule, that any wheel which crosses the 80 per cent. line is a very efficient wheel. Even those makers who have succeeded in getting occasionally an efficiency of 85 per cent. have not been able to maintain this figure with all of their wheels. Where a maker has one wheel showing 85 per cent. he will have in his stock a dozen sizes showing only 82 per cent. or less. Even a wheel of the same size and make, but of the opposite hand, will often fail to reach the same efficiency as its mate.

If the records of the Holyoke testing flume were available to the public, they would probably be found to reduce still further the relative number of abnormally good wheels. For the purpose of comparison, we shall therefore assume 80 per cent. useful effect as the standard for a high-efficiency wheel. It is assumed also that water is furnished to the user in the manner practiced at Lowell, Lawrence and Holyoke, where the water supplied is measured daily. 600 horse-power delivered on the shaft with a fall of 13 feet, and with wheels generally running at full capacity, would require

with 80 per cent. efficiency	509	cubic feet per second,
and with 70 per cent. efficiency	582	" " " "
so that the reduction of 10 per cent. in efficiency involves an additional amount of	73	" " " "

On an 80 per cent. wheel, and with the same fall of 13 ft. these 73 cub. ft. per sec. are capable of developing $85\frac{1}{2}$ H.P. On undertaking to establish a commercial value for these $85\frac{1}{2}$ H.P., we may trench upon

debatable ground, for different engineers have different methods of estimating such values.

At Lowell, where the writer was for several years connected with the corporation managing the water power of the Merrimack River, the rainfall records of the years 1888, 1889 and 1890 were almost phenomenal. The "flood-water" stage of the river prevailed for 72 per cent. of the whole period mentioned and "ordinary water" stage during nearly all of the balance.

To base our calculations upon these conditions would reduce the annual cost of water power at Lowell to a minimum, assuming the rates to be always as at these dates, viz., $4.00 per mill power of 85 gross horse-power per day during "ordinary water" stage, and $2.00 per mill power per day during flood water stage.

For the period indicated the average annual cost on the above basis, and assuming again 80 per cent. efficiency, was $11.64 "on the shaft," from which we have 85½ horse-power at $11.64 per annum = $995.22 as the actual cash paid for water used in excess of what would have been needed with the 80 per cent. wheels. This is the interest at 6 per cent. on $16,500, and when it is stated that the entire cost of an equipment having wheels of 80 per cent. efficiency should not have exceeded $15,000, exclusive of masonry and long feeders, adapted alike to either equipment, it will be seen that the difference in first cost between the best and the poorest could well have been afforded; besides the chances are very great that the lower-priced equipment would have been of much lighter weight, canceling at once part of the difference in cost.

Another view of this valuation would obtain at a country mill, where the owner controls the entire stream, or in localities where its flow is divided among several mill owners *pro rata* to certain established rights in it. This view may be indicated as follows: The streams of New England will, on the average, furnish during many months in the year sufficient water to supply the low-efficiency wheels and probably a large waste besides. Under these conditions the loss due to low efficiency can, logically, be charged against the wheel for only that portion of the year during which the stream fails to meet the demands of the wheel, and the deficiency in power is made up by steam.

It is not unreasonable to assume that the stream will exhibit this deficiency during three months in the year, and that the loss of efficiency is chargeable for such length of time. The loss is thus reduced to 85½ horse-power for one-fourth of the time, or to one-fourth of 85½ horse-power (say 21 horse-power) all the time. Now, what 21 horse-power would be worth depends upon many circumstances which more properly come within the scope of a comparison of the cost of steam and water

power. If, for the sake of the argument, the value of water power is placed at $10.00 per horse-power "on the shaft," the loss of 21 horse-power amounts to $210.00, which is the interest at 6 per cent. on $3,500. Even if the power is assumed to be worth only $5.00 per horse-power, the resulting loss, capitalized at 6 per cent., will be about $1,750, which is still more than 10 per cent. of the first cost of the high-efficiency equipment at $25.00 per horse-power. Each case will present an individuality in this respect as well as in many others, but the engineer can in any case decide how much his client can afford to pay for equipment, and the writer believes that cases will very rarely occur where it is not economical to install an equipment of high efficiency. The case cited is no doubt an extraordinary one; but it indicates to what extent the subject of efficiency is worthy of consideration.

In a case which came under the writer's observation at Minneapolis, two water wheels of the same make and having heavy cast-iron buckets were taken out of their respective wheel-pits to make way for improvements, and it was found that on the convex side or back of every bucket in each wheel the metal had been eroded over an area as large as a man's hand. At the outer limits of each space the erosion was but slight, but it gradually deepened until, at the center of the space, and at almost exactly the same spot on each and every bucket, a hole about an inch in diameter had been worn completely through the iron. From a credible witness it was learned that several other wheels of the same make, taken out of their pits on the same power, exhibited the same condition; and further information developed the fact that a new wheel of this same make, after having been started up in a mill and shut down at the end of a run of about 36 hours, showed on inspection that this process of erosion of the buckets had already begun.

The buckets were no doubt improperly designed for the head of 50 feet under which they worked, and the erosion was probably due to eddies within the wheel, for such eddies must have caused a perpetual drilling or scouring action from the grit carried in suspension, for which the water of the Mississippi is noted. So far as the writer is aware such action has not been noticed in any other make of wheel, either on the Minneapolis power or elsewhere. The very pertinent question then arises: What efficiency could such a wheel have developed when harnessed to the mill work?

Water-wheel builders commonly believe that the higher the fall under which a wheel is tested, the higher will be the efficiency shown. This belief has probably grown out of the phenomenally large percentages of efficiency shown in tests of small wheels under heads of from 18 to 20 feet or thereabouts. There are theoretical considerations which tend to substantiate such a belief, and it therefore behooves the engineer,

when conducting an acceptance test, to have the head conform as nearly as possible to that under which the wheel will operate when installed in the mill. Incidentally it may be suggested that it is well to observe the same condition when obtaining a discharge rating, as for the purpose of using the water wheel as a meter for gaging water, although it is very generally admitted that the discharge of a wheel is proportional to the square root of the head operating upon it, as is that of a fixed orifice. To test and gage a wheel, as a meter, at the Holyoke testing flume under 12 or 13 feet head, and afterward install it at Minneapolis to operate under a head of 50 feet, and to use the basis of the Holyoke test in charging the mill owners for the water used, is a method open at least to the suspicion of incorrectness.

Peculiarities of construction, and the durability and strength of the parts must also be considered. Most of the wheels in the market to-day are made largely, if not entirely, of cast iron. When suitably designed to withstand the heads under which they are to operate, and conscientiously constructed, such wheels are very durable. One of the best wheels on the market has its buckets stamped from plate steel and fastened to the hub and rim at the time of the casting of the latter.

All progressive makers will construct to order wheels whose vital parts are of bronze, but this adds very materially to the cost. Some makers of cast-iron wheels make a separate cast of the buckets, and, after smoothing and polishing them to a reasonable degree, make a second cast, uniting the buckets to the hub and crown. Other builders make the entire wheel at one cast, with the result that the bucket surfaces are left just as they come out of the sand. These rough surfaces are hardly conducive to high efficiency. The maker, in placing these goods upon the market, frequently guarantees a proper percentage of efficiency, taking his chances that no technical acceptance test will be made; and the engineer can protect himself against imposition only by providing in his contract for an acceptance test either *in situ*, or at some such place as the Holyoke testing flume. The cost of a test at the latter place is not excessive, and the writer is satisfied that such a test is as satisfactory as one *in situ*, provided similar conditions as to head and setting obtain.

To Mr. A. M. Swain, of North Chelmford, Mass., undoubtedly belongs the distinction of revolutionizing the form of water wheel, substituting an inward and downward for an outward flow; but to Mr. John McCormick, of Holyoke, Mass., belongs the credit of enlarging the openings to an extent not realized by any other designer. This is exemplified in his "McCormick's Holyoke Turbine" and its prototypes.

By reducing the number of buckets and of guides, he has so materially increased the size of the openings that many of the floating

obstructions which abound in rivers are now allowed to pass through his wheel without injury to it, and without clogging its channels. Wheels of the older style often become entirely stalled from a run of eels or from an accumulation of leaves, sticks, and other débris floating in the stream, entering the wheel and choking its channels until the wheel refused to turn.

The openings in the 100-inch Boyden wheel at the Tremont Mill, the test of which is given in Mr. Francis' "Hydraulic Experiments," were forty-four in number and measured about 5 inches circumferentially at the inlet. They were 11 inches high. A 72-inch Swain wheel of somewhat greater capacity has 25 openings, 8¾ inches by 14 inches high; and a 48-inch McCormick wheel, of about the same capacity as the 100-inch Boyden, has 19 openings, about 8¾ inches by about 19 inches; yet, in spite of this very great increase, the percentage of efficiency has been kept up to a high mark. These figures simply indicate in a general way, and with sufficiently close approximation, the differences between the types of wheels, and are not intended as accurate records of the least cross-sections of their water passages.

Much has been written as to the relative merits of wheels of low speed and large diameter and those of high speed and small diameter. In considering this subject it must be borne in mind that this matter of speed is relative merely, for a wheel of given size develops different speeds under different heads. To ensure the highest efficiency the outer circumference of a wheel of the type under discussion must run at about 70 per cent. of the velocity due the head.

In the adoption of a wheel the engineer must have in mind the delivery of the power developed, for the selection of the wheel is frequently governed by the manner in which this delivery must be effected. As a rule, old mills ran slowly; but competition now demands higher speeds and correspondingly greater power.

Electric machinery usually requires fast-running wheels, and ordinary falls are insufficient to drive this class of machinery without recourse to counter-shaft driving, which is quite objectionable, as well as expensive.

It is evident that where a moderate fall is used a reasonably high initial velocity of wheel is desirable, inasmuch as it permits the use of small gearing, which is less expensive in first cost, more easily maintained, less likely to break, and, if broken, much more quickly replaced. It reduces also the weight, and thus the cost, of the shafting and bearings required.

Again, the high-speed wheel, with its proper casing and other accessories, occupies very much less space than a large wheel, and thus permits the development of greater power within a given space. This

is well illustrated in the case of the Tremont and Suffolk Mills, at Lowell, where in 1890 six high-speed wheels were installed on the Tremont side, in three masonry pits which formerly accommodated three 100-inch low-speed Boyden wheels, which, according to Mr. Francis' test, yielded under 13 feet head about 154 horse-power each, and made 65 revolutions per minute. The new wheels, substituted for these Boydens, yielded under 13 feet head about 149½ horse-power each, and made 88 revolutions per minute, thus nearly doubling the power previously developed in each pit and at the same time increasing the initial velocity of the wheel shaft over 35 per cent. The forebays and feeders were retained just as before, up to the inner wall of the wheel pit.

The results obtained by the writer in making the acceptance test of one of these six wheels at the Holyoke testing flume are recorded further on.

WHEELS OF REDUCED CAPACITY.

The Tremont and Suffolk wheels were specially designed for the purpose of discharging a certain amount of water. Ordinarily, that method affords much the best satisfaction in the long run. Many makers, however, produce a "cut-down" wheel by a "stopped-off" pattern. On high falls it is often necessary to select that diameter of wheel, which will give the desired number of revolutions per minute, and then to reduce its power by reducing its depth, so that its discharge will be more nearly gaged to the flow of the stream. The writer believes, however, that this very ingenious and apparently inexpensive method of reducing the wheel capacity, which, with a full-gate wheel, furnishes a very pretty solution of a frequently occurring problem, should be looked upon with grave distrust when the efficiency of the wheel is to be maintained below three-fourths water.

THE "THREE-QUARTER GATE" WHEEL.

Some wheels are so designed as to give their highest efficiency when the discharge is about three-quarters of the maximum; and this apparent anomaly has its field of usefulness. In mills where water power is the sole motor it must, of course, be made amenable to governing, and to do this the zero point of regulation of the wheel must be at such a point below full gate as to allow one-half of the changeable load to be taken care of by the difference in power at the two points of the gate. Now, if the efficiency of the wheel is greater at this zero point than at full gate, it is evident that during the whole fluctuation of load from maximum to minimum such a wheel would be using water with much better efficiency than one whose maximum efficiency is at full gate. For a mill using both water and steam upon a connected shaft

this method has no advantage, for here the wheels would ordinarily run at full gate, and the regulation would be accomplished by means of the steam engine.

In the table on page 220 it will be seen that at three-quarter discharge the Swain 48-inch wheel developed nearly 81 per cent. efficiency, and the McCormick wheels about 80½ per cent.

COMMERCIAL FEATURES.—DERIVATION OF ELEMENTS INDICATIVE OF RELATIVE CAPACITY OF TURBINES.

Many manufacturers publish elaborate catalogues describing the performances of their wheels. Some of these records are honestly computed, but many are mere compilations, while some are copied *verbatim* from standard catalogues. Stress is often laid upon some peculiar feature developed in a wheel in that famous competitive test made at Holyoke in 1879, and it is really wonderful to note how many of the wheels there tested excelled all the others. One manufacturer unblushingly offers to the guileless public a wheel producing 125 per cent. efficiency.

Under these circumstances it is no easy task to select the "best" wheel, and yet the really best wheels can be counted on one's fingers.

To enable the engineer to judge quickly and intelligently of the characteristics of various types of wheels, the writer has conceived a method of deriving the water-wheel elements, and has illustrated the same by the use of published tests and of such other data as were available. Unfortunately, the data have proved to be exceedingly scarce, for many makers regard the tests of their wheels as a trade secret, and are exceedingly chary of publishing their results.

The method adopted by the writer was to assume that the discharge of the Hercules, Victor, Swain and some other wheels is proportional to the squares of the diameters, each for its own pattern. For a partial verification of this assumption there have been collected, among other tests, those of thirteen wheels, all of different sizes but of the same make, with inward and downward discharge, the tests being made under falls varying from 10½ to 18 feet. The results are shown in Table I, page 214 and in Fig. 1, page 215. A study of these tests, taking the capacity of each wheel as represented by that experiment which showed its maximum coefficient of useful effect, showed conclusively that both the discharge and the power, in this particular make and type, could both be assumed, without sensible error, as proportional to squares of the diameter. The maximum deviation of the discharge from a mean curve, based upon the writer's assumption, was about 6½ per cent., and the average deviation 2.79 per cent.

Naturally the variation of the power would be expected to follow

about the same law as the variation of the discharge, but in the former case the coefficient of useful effect exerts an influence, and hence we find that the maximum variation in power from a similar mean curve is about 4 per cent., while the average variation is 2.62 per cent.

The thirteen wheels showed a range of about 6 per cent. in efficiency, and the average efficiency was a trifle over 81 per cent.

While this single set of experiments with wheels of one make does not fully establish for water wheels in general the law of variation in proportion to squares of diameters, yet it would appear to be a safe basis on which to build the method of derivation.

For any given make of wheels under a head of 1 foot, let

$$\left.\begin{array}{l} P', P'', P''', \text{etc} = \text{the horse-power.} \\ Q', Q'', Q'', \text{etc.} = \text{the discharge in cub. feet per second.} \\ R', R'', R''', \text{etc.} = \text{the revolutions per minute.} \\ D', D'', D''', \text{etc.} = \text{the nominal diameter in feet.} \end{array}\right\} \begin{array}{c} \text{Of any wheel} \\ W', W'', W''', \\ \text{etc.} \end{array}$$

$$Cp = \frac{P'}{D'^2} = \frac{P''}{D''^2} = \frac{P'''}{D'''^2}, \text{ etc.} = \text{coefficient of power.}$$

$$Cq = \frac{Q'}{D'^2} = \frac{Q''}{D''^2} = \frac{Q'''}{D'''^2}, \text{ etc.} = \text{coefficient of discharge.}$$

$$Cr = R'D' = R''D'' = R'''D''', \text{etc.} = \text{coefficient of speed.}$$

Then, for the power P, discharge Q and speed R of any other wheel of the same make, of any other nominal diameter D and under any head h, we have approximately:

$$P = Cp\ D^2\ h^{\frac{3}{2}}\ *.$$

$$Q = Cq\ D^2\ h^{\frac{1}{2}}\ *.$$

$$R = \frac{Cr}{D}\ h^{\frac{1}{2}}\ *.$$

NOMINAL DIAMETERS.

In many of the wheels on the market the diameter of the outlet cylinder is greater than that of the inlet cylinder. The Swain wheel is, in fact, the only one known to the writer in which the limiting cylinders of the inlets and the outlets are of equal diameter. When the runner is a frustum of a cone, we have a range of diameters, from its smallest to its largest, by which to characterize the wheel; *e. g.*, a frustum having a top diameter of 44 inches and a base diameter of 52 inches may be catalogued by any diameter from 44 to 52 inches, whereas in the printed catalogues the nominal diameters differ by only three inches. Such a wheel has an outlet area as large as though the runners were cylindrical and 52 inches in diameter. Hence, some of the wheels in our Table III appear at a very great apparent disadvan-

*A table of $h^{\frac{1}{2}}$ and $h^{\frac{3}{2}}$ is given in table, page 213.

tage, notably the Boyden and the Jonval wheels, the extreme diameters of which are taken as the nominal ones. The Swain wheel also suffers in comparison with the Hercules, which has its outlet areas circumscribed by a cylinder larger than the base of its inlet areas, and in which the latter are tapered, their mean diameter being taken as the nominal diameter of the wheel. If in our table we were seeking an exact comparison of capacities of wheels *of a given diameter*, many of the makes given should be characterized by larger diameters. The Tremont and Suffolk wheel, the test of which is given, would then appear as a 52-inch wheel.

Nevertheless, the table, as intended, presents a convenient method of deriving approximate coefficients of horse-power, discharge and speed for any given type of wheel under any head.

The application of such a table presupposes that the various types of wheel are made in some standard proportion in their various sizes, *e. g.*, some makers make the gate-lift 33 per cent. of the diameter, while others make it 40 per cent., and so on; and it goes without saying that coefficients derived from a test of one wheel can apply to another of the same make only when the gate-lift bears the same ratio to diameter in both cases.

The tests are taken from the following authorities:

100-inch Boyden, pp. 32 and 33, *Hyd. Expts.* James B. Francis.
100-inch IXL Humphry, *Trans. A. S. C. E.*, Vol. XIII, No. 288, Sept. 1884. James B. Francis.
72-inch Swain, *Jour. of the Franklin Inst.*, April, 1875. James B. Francis.
90-inch Boyden, *Trans. A. S. M. E.*, Vol. VIII, No. 243. Test by Clemens Herschel. Prof. Robert H. Thurston.
90-inch Collins-Jonval. Test by Clemens Herschel.
42-inch Swain. Test by Clemens Herschel.
51-36-15-inch (R. H.) 15 (L. H.) Hercules. Test by Clemens Herschel.
84-36-inch Geyelin-Jonval. Test by Samuel Webber.
48-inch Victor (T. & S. Special). Test by the Writer.
39-inch Victor (Trade Pattern). Test by the Writer.
48-inch Swain, courtesy of the Swain Turbine Co. Test by Holyoke Water Power Co., May, 1891.
Several sizes, McCormick's Improved Holyoke, by courtesy of J. B. McCormick. Tests by Holyoke Water Power Co.

Incidentally it may be mentioned here that the reduction of the discharge of wheels to a fall of one foot facilitates the computation of water measurements, and thus effects an important economy of labor at such places as Lowell, Lawrence and Holyoke, where such business is a daily routine.

The quantity of water discharged by a water wheel on any fall h may be obtained by multiplying the discharge under one foot fall by

the square root of h; and this multiplication can be easily performed by means of the slide rule, using the 20-inch scale, from which four figures can be taken off with reasonable accuracy. The fourth figure, ordinarily, would be in the first place of decimals, corresponding to tenths of a cubic foot per second. Equal accuracy might be obtained by the use of Crelle's tables, first writing over every "page multiplier" its square, which would represent the actual fall or h for which the wheel discharge is to be computed.

DEDUCTION FROM TEST OF 48-INCH VICTOR WHEEL.

Referring now to the power-curve on our diagram, Fig. 2, it will be seen to be very much flatter on the right of the summit than on the left. This is due to the fact that as we pass from the summit to the right, the relative velocity and efficiency are decreasing and the discharge increasing; while as we pass from the summit to the left, the reverse condition obtains; the relative velocity increasing, and the discharge and efficiency decreasing. From this law it follows that in designing a wheel for any locality it is advantageous to adapt it to a fall much lower than that which is expected to obtain, rather than to one as high or higher. Other considerations would probably lead, in some degree, to the same judgment, but this one is to be particularly emphasized where this feature of the power-curve becomes so prominent as it is in this make of wheel.

This feature can be used to advantage also in making choice of transmitting gears in cases where specially-constructed gears might be required in order to obtain the requisite line-shaft speed and to maintain the most effective velocity of the wheel. By selecting in such cases gearing of such ratio as to keep the line-shaft up to speed while allowing the wheel to "run slow," some sacrifice of efficiency will be made; but, on the other hand, greater power will be obtained than with a gearing which allows the wheel to "run fast."

TIGHT-SHUTTING GATES—DURABILITY.

So far as the writer has observed, the cylindrical gate gives, all things being considered, the best satisfaction. It can be packed with leather and made almost absolutely water-tight, as has been proved in the Boyden, Swain and Victor wheels. When water is rented at high cost, this is an important factor. The success attendant upon the attempts to pack the register gate must be regarded as questionable; for a very little wear develops leaks and packing soon becomes useless. Again, it is a well-established fact that a wheel with cylindrical gate retains its percentage of efficiency while the quantity of water (and consequently the gate opening) is being diminished, better than a wheel

with the register gate. Floating débris frequently becomes entangled in the openings of the register gate, and the gate cannot then be closed sufficiently to stop the wheel and the machinery attached. The wheel can then be stopped only by closing the head gates, and, in case of an accident to the machinery, much damage might occur while this was being done. The same obstruction under a cylindrical gate would not admit sufficient water to turn the wheel.

The life of a wheel is, of course, a very important factor in guiding a selection; but definite data on this subject seems to be lacking. At Lowell, many of the old-time Boyden wheels have been renewed after a service of about thirty years, probably averaging not over ten and a half hours per day. The Swain wheels installed at the Boott Cotton Mills in 1871 are still running and apparently in good condition.

The writer has seen an old-pattern (register gate) "Victor" wheel, developing 1400 horse-power, taken from the pit of one of the largest flour mills in Minneapolis after a continuous service (night and day) of over eleven years (equivalent to about twenty-five years of service on the New England basis); and this wheel, at a cost of about fifty dollars, could have been replaced in the pit with the prospect of rendering faithful service for many years to come.

RÉSUMÉ.

To sum up; the main points to be secured in selecting a turbine are:

First.—High efficiency (which cannot be obtained with rough blades).

Second.—Good weight and stability of design. Due consideration should be given to the ease with which a wheel can, if necessary, be removed from its case. Some designs are very faulty in this respect.

Third.—Good, tight-shutting gates, well adapted for packing.

Fourth.—The wheel should give the power and speed best adapted to the given fall.

Fifth.—Workmanship, weight, cost and promptness of delivery should be considered.

ACCEPTANCE TEST OF A SPECIAL 48-INCH VICTOR TURBINE AT THE TREMONT AND SUFFOLK MILLS, AT LOWELL, MASS., 1890.

(See Table II and Fig. 2, pages 216 to 219.)

The turbine experimented upon, with the results shown in the accompanying table, was one of six placed in the wheel-pits of the Tremont and Suffolk Mills, at Lowell, Mass., under contract, by the Stilwell and Bierce Manufacturing Company, of Dayton, Ohio, to develop 150 horse-power each under 13 feet fall, and to yield an efficiency of 80 per cent.

To do this, it was necessary to build a wheel from special patterns, for the openings of the 48-inch "trade" wheel would have been too large for the amount of water at disposal; hence, in considering the results, it should be borne in mind that the wheel was designed to use a certain available quantity of water. The result showed 149½ horse-power and 82½ per cent. efficiency.

The experiments were made at the Holyoke Testing Flume, on December 3 and 4, 1890, using the apparatus with which this flume is equipped. The weight of the dynamometer and shaft above the first coupling was 5,400 pounds, and was not counterbalanced in any way. When the flume was empty, a tangential strain of 15 pounds, applied at a distance of 3.2 feet from the center, sufficed to start the wheel.

The wheel is entirely of cast iron. The buckets were first cast separately, and then, after being polished, they were set in a mould and the hubs and crown were cast to them. A steel ring is shrunk on the outside of the blades, and the water enters above this ring and discharges below it. The wheel has seventeen buckets, with a total outlet of 8.37 square feet. The guides are 26 in number, and have an inlet area of 7.92 square feet. The weight of the wheel and of the dynamometer was borne entirely on the step at the foot of the shaft. The wheel was set with its shaft vertical, and with a draught-tube whose submergence was 1.65 feet plus the depth on the weir. The bottom of the draught-tube was 4.2 feet from the floor of the pit.

The flow of water through the wheel is inward and downward through the channels formed by the blades of the runner. The water is received at a vertical rectangular orifice in a cylindrical surface concentric with the shaft, and is discharged through a lune-shaped orifice in a vertical plane drawn radially from the shaft, and below the steel ring referred to. Outside of the runner is a sleeve or cylindrical gate operating by a direct lift, and outside of this gate is the ring or case carrying the guide blades. This gate had a leather packing, and the measured leak through or past the packing at the time of the test was only about .02 cubic feet per second.

The measurement of the power developed by the wheel was made by means of a Prony dynamometer having the following dimensions:

Distance from point of attachment of friction brake link to center of wheel shaft: $\frac{6.383}{2}$ feet.

Length of long arm of lever: 4.5885 feet.

Length of short arm of lever: 0.4585 feet.

Making the circumference of the circle described about the center of the water-wheel shaft by the point of application of the weight in the scale-pan: $2\pi \frac{(6.383)}{(\ 2\ )} \times \frac{(4.5885)}{(0.4585)} = 200.681$ feet.

The lever arm remained practically horizontal throughout, the index recording in only a few cases an elevation of $\pm$ 0.01 foot.

One hundred and fourteen experiments were made; but the first seventy covered the entire range, the remaining 44 being duplicate tests made for the purpose of verification. This verification was so close that one curve satisfies either set of experiments. The table is reproduced graphically in Fig. 2, where the points in the discharge curve are figured to show the discharge relatively to that obtained in the experiment giving the maximum coefficient of discharge. The coefficient of the discharge through the guide openings, for full gate and relative velocity of 0.70, is 0.543.

NOTES ON TABLE II.

Column No. 2.—Height of speed-gate opening.—At every setting of the gate these openings were calipered at three places in the circumference of the wheel, always using the same three places. To do this it was necessary to empty and refill the flume several times; but with the excellent appointments of the Holyoke Testing Flume but little extra time was consumed in this process.

In many wheel tests dependence has been placed upon some device for automatically registering the speed-gate opening, but the writer is convinced that this method is not always reliable. Its failure may be due to " back lash " in the gears or to elongation of the connecting chain, or to both causes combined.

Column 4.—All the weights used were sealed by the city sealer of weights and measures.

Column 5.—The number of foot-pounds per second of work done is obtained by multiplying together the revolutions per second of the wheel, the circumference of the effective circle and the weights in the scale pan.

Column 6.—The depths on the weir were measured in the usual manner by a hook-gage.

Column 7.—The discharge was measured over a weir 20.032 feet long, without end contractions. Its crest was 5.85 feet above the bottom of the channel of approach. This channel was of rectangular section and 35 feet long, and provided with racks located respectively 15 and 27 feet above the weir. The flow was computed by the formula given in the Lowell Hydraulic Experiments, viz., $Q = 3.33 \text{ L. H. } \frac{3}{2}$, and was corrected for velocity of approach by the method indicated by the writer and Mr. Frank S. Hart in the *Journal of the Franklin Institute*, August, 1884. Care was taken to keep the water on the downstream side of the weir more than three-tenths of a foot below the crest in every instance, so as to prevent any effect on the flow over the weir.

Careful measurements of the leak into and out of the wheel-pit were made, and showed that the resultant leak was 0.03 cubic feet per second, so that the figures in Column 7, increased by 0.03, give the discharge over the weir. The water used for cooling and for lubrication was measured through a meter, but, as it was discharged into the flume directly over the wheel being tested, it in no way affected the discharge over the weir.

Column 9.—The temperature of the water during the test was 32° F., and the weight of the quantity discharged per second (taken at 62.373 lbs. per cubic foot), multiplied into the observed fall acting on the wheel, gives the foot-pounds per second of energy in the water passing the wheel.

Column 10.—The figures in this column are obtained by dividing those in Column 5 (foot-pounds per second of work) by those in Column 9 (foot-pounds per second of energy of water).

Column 11.—It will be seen that the coefficient of useful effect varies with the speed at which the wheel runs, and their ratio is useful in comparing results.

TABLE OF $h^{\frac{1}{2}}$ AND $h^{\frac{3}{2}}$ FOR EACH HALF-FOOT FROM 1 TO 40 INCLUSIVE.

h	$h^{\frac{1}{2}}$	$h^{\frac{3}{2}}$	h	$h^{\frac{1}{2}}$	$h^{\frac{3}{2}}$
			20.5	4.5277	92.8177
1.0	1.0000	1.0000	21.0	4.5826	96.2341
1.5	1.2247	1.8371	21.5	4.6368	99.6914
2.0	1.4142	2.8284	22.0	4.6904	103.1892
2.5	1.5811	3.9528	22 5	4.7434	106.7269
3.0	1.7321	5.1962	23.0	4.7598	110.3041
3.5	1.8708	6.5480	23.5	4.8477	113.9205
4.0	2.0000	8.0000	24.0	4.8990	117.5755
4.5	2.1213	9.5459	24.5	4.9497	121.2688
5.0	2.2361	11.1803	25.0	5.0000	125.0000
5.5	2.3452	12 8986	25.5	5.0498	128.7687
6.0	2.4495	14.6969	26.0	5.0990	132.5745
6.5	2.5495	16.5718	26.5	5.1478	136.4171
7.0	2.6458	18.5203	27.0	5.1962	140.2962
7.5	2.7386	20.5396	27.5	5.2440	144.2112
8.0	2.8284	22.6274	28.0	5.2915	148.1620
8.5	2.9155	24.7815	28.5	5.3385	152.1483
9.0	3.0000	27.0000	29.0	5.3852	156.1698
9.5	3.0822	29.2810	29.5	5.4314	160.2260
10.0	3.1623	31.6228	30.0	5.4772	164.3168
10.5	3.2404	34.0239	30.5	5.5233	168.4417
11.0	3.3166	36.4829	31.0	5.5678	172.6007
11.5	3.3912	38.9984	31.5	5.6125	176.7933
12.0	3.4641	41.5692	32.0	5.6569	181.0193
12.5	3.5355	44.1942	32.5	5.7009	185.2786
13.0	3.6056	46.8722	33.0	5.7446	189.5706
13.5	3.6742	49.6022	33.5	5.7879	193.8953
14.0	3.7417	52.3832	34.0	5.8310	198.2523
14.5	3.8079	55.2144	34.5	5.8737	202.6416
15.0	3.8730	58.0947	35.0	5.9161	207.0628
15.5	3.9370	61.0235	35.5	5.9582	211.5157
16.0	4.0000	64.0000	36.0	6.0000	216.0000
16.5	4.0620	67.0233	36.5	6.0415	220.5156
17.0	4.1231	70.0928	37.0	6.0828	225 0622
17.5	4.1833	73.2077	37.5	6.1237	229.6397
18.0	4.2426	76.3675	38.0	6.1644	234.2477
18.5	4.3012	79.5715	38.5	6.2048	238.8862
19.0	4.3589	82.8191	39.0	6.2450	243.5550
19.5	4.4159	86.1097	39.5	6.2849	248.2536
20 0	4.4721	89.4427	40.0	6.3246	252.9822

TABLE I.

POWER AND DISCHARGE OF THIRTEEN WATER-WHEELS, AS GIVEN BY ACTUAL TEST AND AS COMPUTED BY THE SQUARES OF THE DIAMETERS. THE WHEELS WERE OF THE SAME MAKE, WITH INWARD AND DOWNWARD DISCHARGE, BUT OF DIFFERENT DIAMETERS. THE TABLE IS REPRODUCED GRAPHICALLY IN THE DIAGRAM OPPOSITE.

No.	Horse-Power.				Discharge.			
	From tests.	Computed. Mean Curve.	Variation from Mean Curve. In H. P.	Variation from Mean Curve. Per Cent.	From tests. Cub. ft. per Sec.	Computed. Mean Curve. Cub. ft. per Sec.	Variation from Mean Curve. Cub. ft. per Sec.	Variation from Mean Curve. Per Cent.
1	6.10	6.00	+ 0.10	+ 1.67	5.17	5.02	+ 0.15	+ 2.99
2	10.41	10.67	— 0.26	— 2.44	8.79	8.92	— 0.13	— 1.46
3	16.49	16.67	— 0.18	— 1.08	13.85	13.93	— 0.08	— 0.57
4	22.89	24.00	— 1.11	— 4.62	18.85	20.07	— 1.22	— 6.08
5	33.71	32.67	+ 1.04	+ 3.18	29.07	27.32	+ 1.75	+ 6.41
6	41.53	42.67	— 1.14	— 2.67	35.31	35.68	— 0.37	— 1.04
7	56.67	54.07	+ 2.60	+ 4.81	47.81	45.16	+ 2.65	+ 5.87
8	63.69	66.68	— 2.99	— 4.48	54.15	55.75	— 1.60	— 2.87
9	97.45	96.00	+ 1.45	+ 1.50	77.33	80.28	— 2.95	— 3.67
10	109.98	112.68	— 2.70	— 2.40	93.51	94.2[illegible]	— 0.71	— 0.75
11	133.09	130.69	+ 2.40	+ 1.84	107.73	109.27	— 1.54	— 1.41
12	153.82	150.02	+ 3.80	+ 2.53	128.53	125.44	+ 3.09	+ 3.10
13	196.28	192.69	+ 3.59	+ 1.86	161.07	161.12	— 0.05	— 0.03

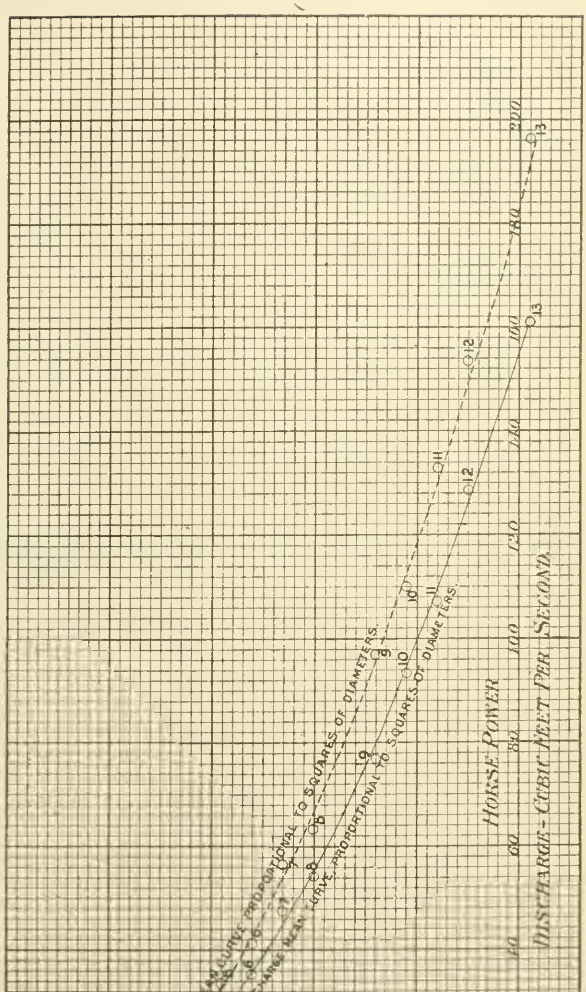


Fig. 1.—Diagram of Table I.

Diagram showing the Discharge and the Horse-power of Thirteen Turbines, as compared with mean curves constructed from the squares of the diameters of the wheels.

Note.—The turbines were all of the same make, with inward and downward discharge.

TABLE II.

EXPERIMENTS MADE FOR THE TREMONT AND SUFFOLK MILLS AT HOLYOKE TESTING FLUME, DECEMBER 3–5, 1890, ON A 48-INCH VICTOR TURBINE, WITH CYLINDER GATE.—SEE DIAGRAM, FIG. 2, PAGES 218, 219.

1. Duration of the experiment.	2. Height of speed-gate opening.	3. Number of revolutions of wheel.		4. Weight in the scale.	5. Useful effect.		6. Depth of water on the weir.	7. Quantity of water discharged by the wheel.	8. H. Fall at the wheel.	9. Total power of the water passing the wheel.	10. Efficiency or ratio of the useful effect to the power expended.	11. Ratio of the velocity of exterior circumference of wheel to that due the fall.	12. Horse-power of wheel under a head of 13 feet.	13. Discharge of wheel under a head of 13 feet.
Seconds.	Inches.	Total during the experiment.	Per minute.	Pounds (Avoirdupois).	Foot-pounds per second.	Horse-power.	Feet.	Cubic feet per second.	Feet.	Foot-pounds per second.		11.		Cubic feet per second.
360.	Full Gate. 20.58	856.	142.7	None.	....	....	1.255	94.49	13.185	....	....	1.1127	....	93.82
300.	"	609.	121.8	100.	40738.	74 07	.335	103.75	.019	84251.	0.4365	0.9558	73.91	103.67
300.	"	523.	104.6	200.	69971.	127.22	.436	115.87	12.951	93602.	.7475	.8230	127.94	116.09
360.	"	602.	100.3	230.	77184.	140.33	.465	119.44	13.200	98341.	.7849	.7817	137.15	118.53
300.	"	480.	96.0	250.	80272.	145.95	.479	121.18	.167	99524.	.8066	.7491	143.18	120.41
360.	"	561.5	93.6	265.	82947.	150.81	.491	122.67	.262	101475.	.8174	.7277	146.36	121.45
360.	"	517.5	91.2	275.	83931.	152.60	.497	123.41	.265	102110.	.8220	.7090	148.05	122.17
360.	"	527.	87 8	285.	83726.	152.23	.499	123.67	.157	101492.	.8249	.6854	149.51	122.93
180.	"	253.	84.3	295.	83210.	151.29	.502	124.05	.139	101665.	.8184	.6585	148.90	123.39
360.	"	498.	83 0	300.	83283.	151.42	.503	124.17	.140	101771.	.8183	.6483	149.01	123.51
420.	"	571.5	81.6	305.	83286.	151.43	.506	124.55	.157	102214.	.8148	.6370	148.73	123.80
360.	"	479.	79.8	310.	82775.	150.50	.507	124.67	.130	102103.	.8107	.6235	148.27	124 05
540.	"	695.5	77.3	317.	81935.	148.97	.509	124.93	.095	102043.	.8029	.6048	147.35	124.48
300.	"	375.	75.0	330.	82781.	150.51	.518	126.05	.221	103948.	.7964	.5840	146.75	124.99
300.	"	350.5	70.1	345.	80889.	147.07	.523	126.67	.201	104302.	.7755	.5163	143.72	125.70
420.	"	Still.	Still.	......	....	....	546	129.60	.081	....	....	....		129.20
300.	$\frac{7}{8}$ Gate (nearly). 17.90	541.	108.2	175.	63332.	115.15	1.374	108.38	13.463	91013.	0.6959	0.8349		106.50
300.	"	516.	103.2	200.	69034.	125.52	.395	110.90	.389	92617.	.7454	.7986		109.28
360.	"	586.	97.7	225.	73499.	133.64	.410	112.71	.324	93672.	.7846	.7578		111.33
360.	"	549.5	91.6	250.	76579.	139.24	.426	114.65	.252	94769.	.8081	.7125		113.55
360.	"	535.	89.2	260.	77541.	140.98	.431	115.26	.235	95151.	.8149	.6942		114.23
300.	"	431.	86.2	270.	77844.	141.53	.436	115.87	.195	95365.	.8163	.6719		115.01
480.	"	666.	83.2	280.	77965.	141.75	.410	116.36	.169	95580.	.8157	.6492		115.61
360.	"	464.	77.3	300.	77597.	141.08	.451	117.72	.242	97233.	.7980	.6015		116 64
240.	"	280.5	70.1	320.	75055.	136.46	.456	118.34	.199	97428.	.7704	.5463		117.44
300.	"	Still.	Still.	......	....	....	.459	118.70	.161	....	....	....		117.97
300.	"	725.5	145.1	None.	....	....	.245	93.35	14.023	.. ..	....	1.0971		89.88

300.	¾ Gate (nearly).	15.38	510.	102.0	170.	57997.	105.45	1.293	98.85	13.043	80420.	0.7212	0.7997	98.69
300.		"	476.	95.2	200.	63683.	115.79	.316	101.53	12.985	82233.	.7744	.7480	101.59
240.		"	362.	90.5	220.	66593.	121.08	.331	103.28	13.049	84063.	.7922	.7093	103.09
300.		"	432.5	86.5	235.	67989.	123.62	.343	104.70	.049	85219.	.7978	.6780	104.50
300.		"	420.	84.0	245.	68834.	125.15	.348	105.29	.029	85567.	.8044	.6589	105.17
300.		"	405.	81.0	255.	69084.	125.61	.354	106.00	.029	86145.	.8020	.6354	105.88
300.		"	387.5	77.5	265.	68691.	124.89	.359	106.59	.017	86544.	.7937	.6082	105.52
300.		"	365.	73.0	275.	67144.	122.08	.364	107.18	.025	87077.	.7711	.5727	107.08
180.		"	206.5	68.8	285.	65614.	119.30	.366	107.42	.024	87265.	.7519	.5398	107.32
300.	⅝ Gate (nearly).	12.90	516.	103.2	140.	48324.	87.86	1.192	87.40	13.193	71923.	0.6719	0.8045	86.76
360.		"	588.	98.0	160.	52445.	95.35	.208	89.19	.159	73206.	.7164	.7649	88.65
180.		"	280.	93.3	175.	54630.	99.33	.218	90.30	.110	73842.	.7398	.7296	89.92
300.		"	456.5	91.3	185.	56493	102.72	.229	91.54	.165	75170.	.7515	.7125	90.96
360.		"	528.5	88.1	195.	57449.	104.45	.236	92.33	.139	75669.	.7592	.6882	91.81
180.		"	253.	84.3	205.	57824.	105.13	.243	93.12	.097	76072.	.7601	.6595	92.77
240.		"	317.	79.2	220.	58315.	106.03	.252	94.15	.062	76708.	.7602	.6205	93.93
300.		"	365.5	73.1	235.	57457.	104.47	.259	94.94	12.993	76943.	.7467	.5742	91.97
300.	½ Gate (nearly).	10.31	507.	101.4	115.	39002.	70.91	1.077	74.98	13.239	61917.	0.6299	0.7891	74.30
300.		"	479.5	95.9	130.	41698.	75.81	.089	76.25	.195	62757.	.6641	.7475	75.68
360.		"	540.	90.0	145.	43648.	79.36	.101	77.52	.137	63521.	.6871	.7031	77.11
300.		"	431.	86.2	155.	44688.	81.25	.107	78.16	.113	63929.	.6990	.6740	77.82
300.		"	413.	82.6	165.	45585.	82.88	.114	78.91	.063	64296.	.7090	.6471	78.72
360.		"	471.	78.5	175.	45948.	83.54	.121	79.66	.027	64728.	.7099	.6158	79.58
180.		"	222.	74.0	185.	45789.	83.25	.129	80.52	.010	65342.	.7008	.5809	80.49
300.		"	360.	72.0	190.	45755.	83.19	.131	80.73	12.999	65457.	.6990	.5654	80.73
240.		"	Still.	Still.	......	....	....	.118	79.33	13.254	....	....	....	78.57
300.		"	615.5	129.1	None.	....	....	0.986	65.62	.437	....	....	.9972	64.54
300.	⅜ Gate. (nearly).	7.80	512.5	102.5	70.	23998.	43.63	0.925	59.59	13.215	49119.	0.4886	0.7983	59.10
360.		"	590.5	98.4	80.	26334.	47.88	.932	60.27	.200	49623.	.5307	.7668	59.81
360.		"	544.5	90.7	95.	28835.	52.43	.941	61.45	.147	50392.	.5722	.7083	61.11
360.		"	517.	86.2	105.	30261.	55.02	.950	62.04	.084	50632.	.5977	.6747	61.81
360.		"	488.	81.3	115.	31284.	56.88	.957	62.73	.039	51019.	.6132	.6375	62.64
360.		"	457.	76.2	125.	31844.	57.90	.964	63.43	.007	51461.	.6188	.5982	63.41
300.		"	357.5	71.5	135.	32285.	58.70	.970	64.02	12.967	51780.	.6235	.5622	64.10
240.	¼ Gate (nearly).	5.23	410.	102.5	25.	8571.	15.58	0.741	42.65	13.094	34834.	0.2460	0.8020	42.50
300.		"	485.	97.0	35.	11355.	20.65	.747	43.18	.059	35172.	.3228	.7600	43.08
300.		"	456.5	91.3	45.	13742.	24.98	.754	43.79	.019	35560.	.3864	.7164	43.76
360.		"	428.5	88.1	50.	14731.	26.78	.756	43.96	.005	35660.	.4131	.6917	43.95
360.		"	511.	85.2	55.	15667.	28.49	.759	44.23	12.972	35788.	.4378	.6698	44.28
240.		"	327.5	81.9	60.	16431.	29.87	.761	44.40	.939	35834.	.4585	.6447	44.50
300.		"	404.	80.8	65.	17566.	31.94	.770	45.19	13.213	37244.	.4717	.6294	44.82
360.		"	446.	74.3	75.	18647.	33.90	.776	45.73	.175	37580.	.4962	.5796	45.43
300.		"	338.	67.6	85.	19219.	34.94	.781	46.17	.133	37821.	.5081	.5282	45.94

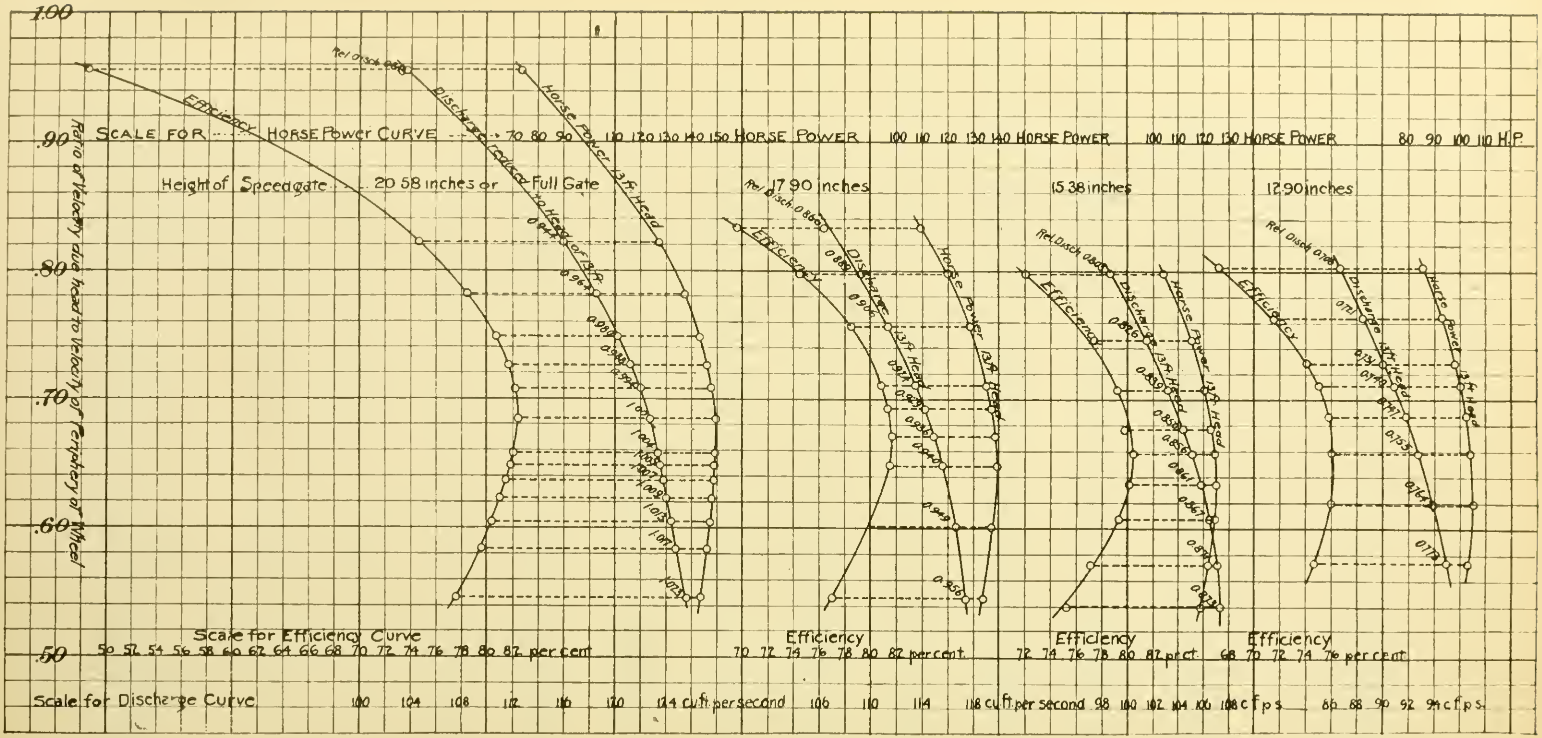


FIG. 2.—DIAGRAM OF TABLE II. (See continuation below.)

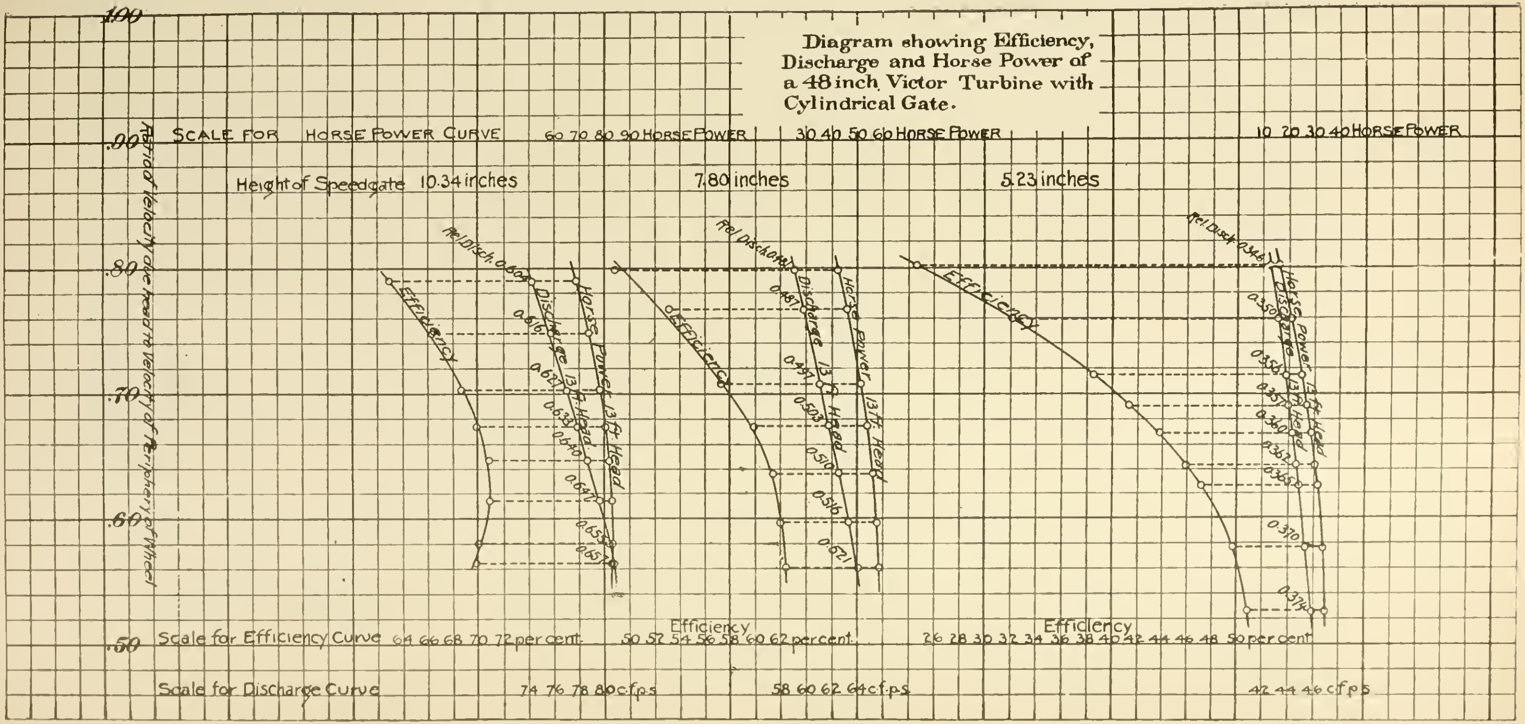


Fig. 2.—Diagram of Table II. (Continued.)

TABLE III.

ELEMENTS OF SEVERAL TYPES OF TURBINE WATER-WHEELS COMPUTED BY THE METHOD OUTLINED ON PAGES 205 AND 206.

Type of Wheel.	Diameter. Inches.	Efficiency.	Fall.	H. P.	Discharge Cub. ft. per Sec.	Revolutions per Minute.	$C_P = \frac{P}{h^{\frac{3}{2}} D^2}$.	$C_Q = \frac{Q}{h^{\frac{1}{2}} D^2}$.	$C_R = \frac{R}{h^{\frac{1}{2}}} D$.	Remarks.
Boyden............	90	80.17	16.60	222.04	147.10	63.5	0.062	0.68	95.	Outward flow.
"	100	79.37	12.90	160.51	138.33	51.1	0.047	0.54	100.	
Collins-Jonval.........	90	85.06	16.59	181.49	113.40	63.7	0.048	0.49	117.	
Geyelin-Jonval	36	83.43	29.30	68.32	24.67	213.5	0.060	0.51	108.	Parallel flow.
" "	84	83.67	29.30	468.85	166.97	76.2	0.077	0.63	99.	
Humphrey	100	81.86	12.48	243.49	210.18	46.3	0.080	0.86	109.	
Swain	42	82.20	14.25	62.81	47.31	119.1	0.095	1.02	110.	
"	48	78.00	16.53	188.48	128.98	105.7	0.175	1.98	104.	
"	72	83.26	12.71	195.93	163.66	70.9	0.120	1.27	120.	
Hercules.	51	82.69	12.77	191.01	159.64	81.7	0.232	2.47	97.	
"	36	85.80	16.96	145.72	88.33	140.6	0.232	2.38	102.	
" (R. H.)......	15	80.80	15.46	21.39	15.10	292.7	0.226	2.46	93.	Inward and downward flow.
" (L. H.)......	15	81.75	17.29	25.41	15.85	347.3	0.226	2.44	104.	
Victor (T. & S.).......	48	82.49	13.00	149.51	122.93	86.7	0.200	2.13	98.	
" (R. H.)	39	80.37	16.00	174.06	119.68	121.2	0.259	2.83	98.	
McCormick's Improved Holyoke ...	Mean of Several Sizes.	81.54	....	....	....	....	0.250	2.73	103.	

DISCUSSION.

Mr. Richard A. Hale.—The subject of Mr. Hunking's able paper has so wide a range, depending on the situations that require power plants, that no fixed rule can be applied to all cases. During the last twenty years much progress has been made in the improvement of the turbine, and the manufacturer of the present day, who wishes to install a water power plant, is not satisfied with a certificate that a certain wheel has once accomplished certain results. He wishes instead an actual test of the wheel in a testing flume, to determine its efficiency before acceptance, and the contract is often made on the basis of certain efficiencies to be reached at various openings of the wheel gate. This is the only certain method of knowing how much one is getting for his money, and those who use wheels realize that a difference of 2 or 3 per cent. in the efficiency may mean a difference in their power and hence in their actual money value.

The size and capacity of a wheel for a power plant must be well considered, and in this connection a careful study should be made of the streams on which the wheels are to be located. On a large stream with a constant power, but with variations in the fall, turbines of different capacities and sizes may be so employed as to run with the most economical results at different heights of the water in the river. For example, with one plant of three turbines of different sizes, the work may be accomplished by one turbine at full gate when there is the greatest head on the wheel. As the river rises, causing back water on the wheels, another wheel is added, and the gates are set at such a height as will give the greatest efficiency for the water used. With still further increase in the height of water, the third wheel may have to be added in order to obtain the desired power. By the use of these extra wheels the mill may thus be run at stages of the river when otherwise it would be shut down.

The step supporting the wheel and shaft must be durable and capable of being readily replaced without disconnecting all the parts.

The method of setting turbines on horizontal shafts and using long draft tubes has been in use for some years. It has the advantage of dispensing with the bevel gears and the steps.

There is, however, a wide field for investigation in regard to the percentage of efficiency of horizontal wheels as compared with that of vertical wheels, to the proportions of the draft tube relatively to the wheel outlets, and to the relative advantages between the cylindrical and diverging forms of draft tube. These questions can be settled only by actual tests, and, so far as can be ascertained, testing flumes are not as yet arranged for testing horizontal wheels.

During the past summer experiments were made at Lawrence to determine the discharge of two turbine wheels on a horizontal shaft, with a draft tube about 20 feet in length. The wheels were set in a large iron casing supplied with water from the canal through iron penstocks. Both wheels discharged into one central draft tube, and experiments were made on the discharge of each wheel run separately, and then on both wheels run together at the same heights of gates as when run alone. The water was measured by weirs in the races and the facilities for accurate measurement were first-class in every respect. It was found that when the two wheels were run together the discharge was much less than the sum of the discharges of the two wheels when run alone. This was without doubt due to the collision of the two streams as they left the wheel outlets, and the difference increased as the gates were opened, and, at full gate, amounted to 4 per cent. Hence a separate draft tube should be provided for each wheel. It was found that when the wheel was run alone the discharge, as compared with that of a similar wheel on a vertical shaft, decreased as the speed-gate was gradually raised. The coefficients of discharge of Boyden wheel outlets range from 70 to 75 per cent., while in wheels of the Hercules, Swain and Hunt types the coefficient ranges from 50 to 60 per cent. These coefficients depend on the ratio of the guide outlet area to the bucket outlet area, and are important factors in cases where it is desirable to obtain the discharge of a wheel approximately. The coefficient of discharge of a given wheel can be determined from the ratio between the outlets in a tested wheel of similar type.

With regard to the practice of changing the patterns of a wheel of a certain size, in order to increase its capacity for discharge and power, thus making what is known as a "double capacity" wheel, it is an open question whether the percentage of efficiency is the same as in the ordinary wheel, and tests might well be made to determine this.

Mr. Joseph P. Frizell.—Without attempting to discuss any specific point raised by the paper just read, I will offer a few remarks upon the general subject of water wheels, a subject of special interest to me.

Uriah A. Boyden was chiefly instrumental in introducing the turbine into New England. He was a man of very thorough mathematical attainments, and studied the subject in a broad and philosophic spirit. His best authentic result, resting on indisputable authority, was 88 per cent., but he stoutly maintained his claim to an efficiency considerably above 90 cent. I think that even the smaller of these results has never been equalled or closely approached since his time. Mr. Boyden's wheel was an outward-flow turbine, the water being discharged at the periphery through orifices horizontal in width and vertical in

length, and directed upon the floats of the wheel by guides. The high efficiency of the wheel was the result of the scientific and accurate adjustment of the relations between the area of the guide passages, the area float passages, the direction of the water issuing from the guides and the directions of the inner and outer ends of the floats. The regulating gate was cylindrical and closed between the floats and guides. The defect of the wheel was this: As soon as the regulating gate commenced to close, it deranged the nice adjustment existing between these several factors; and this derangement increased as the gate closed down, so that the wheel worked with greatly diminished efficiency on a diminished discharge. The Proprietors of Locks and Canals at Lowell purchased Mr. Boyden's patents, and many of these wheels were built under supervision of their agent. The wheel described by Mr. James B. Francis in the Lowell Hydraulic Experiments gave an efficiency of 79 per cent. On a critical examination of the design of this wheel I think I detect the cause of this discrepancy in a lack of the accurate adjustment above referred to, but I cannot now go into details on that point.

The above defect in the Boyden wheel, together with its high cost, led to its gradual abandonment, but many are still in use. At present the business of making turbines is in the hands of mere machinists. Good machinists undoubtedly and men of good judgment and business capacity, but with very little knowledge of the mechanical principles involved in the action of the turbine wheel. I have never yet seen the circular of a wheel maker which evinced any rational conception of the principles of hydrodynamics or any intelligent comprehension of the action of water upon his wheel. The forms now in the market are the result of experiment uncontrolled by accurate knowledge. They are, it is fully conceded, durable and convenient in design, ready of application, excellent in workmanship and of reasonable efficiency; but I desire to say emphatically that this efficiency could be improved by more thorough knowledge and more intelligent application of mathematical principles. It is customary to say that turbines go by water, but it cannot be denied that the sale of water wheels goes largely by wind, and the success of wheel makers depends to a much greater extent upon their skill in the use of the latter agency than of the former.

All modern turbines, or substantially all, discharge the water through orifices, whose length is measured on the radius and whose width is measured on the circumference. In some the length of this orifice is as great as two-thirds of the radius. Nothing is more clearly demonstrable than the fact that this arrangement is inconsistent with the highest efficiency. The velocity of the water, depending on the head, is constant in all parts of the orifice, but the well-known condition of maximum efficiency is, that the water shall leave the wheel with the

same velocity that the wheel has at the point of discharge. Otherwise the water carries away energy which has not been imparted to the wheel. In the wheels I speak of, this condition cannot be fulfilled, because one end of the orifice moves often with a velocity twice as great as the other. Hence I say that wheel makers are on the wrong road, and have adopted a form radically inconsistent with the best results.

Another conclusion to which my studies and reflections have led me will probably be received with some surprise. I am prepared to affirm that guides, intended to give the water a suitable direction on entering a turbine wheel, are unnecessary appendages, and that in a properly constructed wheel the water entering the wheel will spontaneously take the direction most conducive to efficiency.

The designs of Mr. Boyden were matured with great care, and each wheel was adapted to the special conditions under which it was required to move. The rigid and elaborate tests made by him and the accurate workmanship he insisted upon were exceedingly expensive. After his time an urgent demand arose for cheaper wheels and cheaper engineering, a demand which has been met to the full satisfaction of mill owners. In fact, many of them have been more than satisfied. A class of hydraulicians arose who discarded all unnecessary nicety, derided scientific attainments, and were prepared to make tests sufficiently accurate for all practical purposes for the twentieth part of what such operations had formerly cost.

Wonderful results have been arrived at by these methods. The man who has been spoken of as claiming a result of 140 per cent. probably made some palpable error, but I have no doubt that a result of 100 per cent. could be arrived at without doing any open and manifest violence to the rules of hydraulics.

The following case is of frequent occurrence: On a stream are two dams half a mile apart or thereabouts. The wheel is at the upper dam, the measuring weir at the lower. During the test the water rises a little at the weir. The operator disregards niceties and takes the average height. This takes no account of the water which has passed the wheel and accumulated in the stretch of river between the dams.

Suppose the distance between the dams to be 2,500 feet, the width of the stream 100 feet, the duration of the test 10 minutes, during which the water rises one-half inch. The use of the average height would underrate the quantity of water passing the wheel by $\frac{2500 \times 100}{10 \times 60 \times 24} = 17$ cubic feet per second, and, of course, would overrate the efficiency in like proportion.

The discharge is invariably measured by means of the weir; but it is well known that the weir formula in ordinary use is purely empirical,

and that it does not give accurate results unless the conditions are closely similar to those under which it was deduced. An apparently trifling deviation from these conditions often makes a material error in the result. This point very rarely receives sufficient consideration in such tests.

Not long ago I witnessed a test of the so-called Pelton water wheel. This consists of a series of cup-shaped vessels arranged on the periphery of a wheel and acted on by a jet of water. The action of the water on this wheel is nearer scientific perfection than on any other wheel I know of. The defect of the Pelton wheel is that it cannot be submerged, and that on ordinary falls too great a part of the head is therefore wasted. In the test referred to the flow through the nozzle was controlled by an ordinary valve, which, as is well known, occasions when partly closed a great loss of head; and the head acting on the wheel was estimated from the indications of a pressure gage attached between the valve and the nozzle. The gage thus took no account of the loss occasioned by the valve, a loss which cannot be avoided in the practical operation of the wheel. It appeared to me that this method materially overestimated the useful effect of the wheel.

Prof. Dwight Porter.—The rotation of a turbine or other vaned water wheel is dependent upon the simple mechanical principle that when the velocity of a particle of water is changed in direction or in amount, a force is required to effect the change. The velocity of particles flowing from the guides through the buckets of a turbine *is* changed in direction and in amount, and the force thus developed turns the wheel.

In order to understand how the work obtainable from this force may be varied by varying the conditions as to speed of rotation and the direction of flow of the entering and the off-flowing water, a study of the theory of the flow of water over curved vanes is important. It need not be carried very far, is not especially difficult, and in large degree may be illustrated graphically. By its aid the tendency of certain arrangements, as regards effect upon efficiency, can easily be shown, and conclusions of much value to the designer can be drawn.

In various ways, the more important of which are not difficult to foresee, and which have their analogy in the ordinary cases of flow of water through pipes, losses of energy result and the efficiency of the motor sinks below unity. Moreover, these losses are variable, and, consequently, the efficiency is variable also, changing both with the speed of the wheel and with the degree of the gate opening. A study, therefore, of the losses of energy occurring between the feeding canal and the tail race, may be as useful to the student as any part of the subject

can be. The attempt to frame precise theoretic expressions for these various losses, and to introduce these expressions into the general equations applicable to the flow through turbines, gives those equations a complicated character which is forbidding to all persons and profitable to but few. In my opinion, therefore, the study should be one of principles, tendencies and limits, rather than a struggle with cumbersome equations. It is not difficult to form an opinion of the relative importance of the various losses, nor, in some cases, to assign reasonable limits to their values. If, further, the principles upon which they rest are known, the designer knows how he should work to lessen them, and therefore knows the most important thing.

The problem of the water-wheel is not altogether one of efficiency, however, but may be one of cheapness, or compactness, or portability, or of adjustment to peculiar service. To the solution of such questions a good all-around knowledge of the features of turbines and other wheels, and a practical acquaintance with their design and construction, must be had, and probably can be gained in but limited degree at a technical school.

The theory of the draft or suction tube should be understood, so that at least the tube shall not be ignorantly called upon for gymnastics to which the suction pump and the siphon are unequal.

The value of the study of the turbine will be greatly enhanced if the study be made in some degree an object lesson. To that end I have in my class-room a 15-inch combination flow turbine, complete and of approved design. This wheel the students take apart and afterwards put together again. It lies in pieces before them during most of the course. Photographs showing sundry arrangements of vertical and horizontal wheels are also used to advantage.

After all the study of theory, and care in designing, the actual success of the turbine is to be found by test only, and for the practical training of the students they are, therefore, required to make the observations and work up the results of tests in the laboratory upon a Swain turbine, as well as of those upon an impulse wheel of the Pelton or other type.

In these statements I have endeavored to indicate the principles upon which is based the instruction in hydraulic motors at the Massachusetts Institute of Technology.

WILLIAM SCHERZER.

A MEMOIR.

By August Zeising and C. L. Strobel,
Committee of the Western Society of Engineers.

[Read April 4, 1894.]

William Scherzer was born in Peru, La Salle County, Illinois, on January 27, 1858. He received his primary education in the public schools of Peru, and later entered the private school of Professor Eggers. In 1875, at the age of seventeen, he went to Zurich, Switzerland, and entered the Polytechnic School in that city to take the regular course in civil engineering. He graduated from that school in 1880. Returning to America, he filled the position of engineer to the Matthiessen & Hegeler Zinc Company at La Salle, Illinois, for the ensuing three years.

In 1883 he entered the employ of the Pittsburg, Fort Wayne & Chicago Railway Company, and thenceforth devoted himself to bridge engineering as a specialty.

In 1885 he accepted the position of principal assistant to the chief engineer of the Keystone Bridge Company, with office in Chicago, and continued in the employ of that company for eight years, until January 1, 1893. He then entered into business for himself at Chicago as a consulting and contracting engineer.

He died on Thursday morning, July 20, 1893, at the early age of thirty-five years. His last engineering work, and a very important and interesting one, was the design of two rolling lift bridges, one to span the Chicago River between Jackson and Van Buren Streets, for the Metropolitan West Side Elevated Railroad Company, and the other, at Van Buren Street, for the city of Chicago. These bridges are now under contract to be built. Their designs are a departure from the plans and methods heretofore adopted for lift bridges, and, it is believed, are an improvement upon them.

Mr. Scherzer was unfortunately deprived of the satisfaction of seeing the construction and successful completion of these structures, for unremitted application to his work, with, perhaps, some lingering effects of an attack of typhoid fever, from which he had suffered a year before, brought upon him his brief, fatal illness, an attack of brain fever.

He was from childhood of a most ambitious nature, and no obstacle ever seemed too great to overcome when he had once started out to accomplish a certain purpose. He was, at the same time, cautious, and

he carefully weighed the chances of failure or of success in an undertaking before going into it. At the Polytechnic School, at Zurich, he was consequently in the front rank in his class, both in play and in work, and was always considered a formidable competitor by all intimately acquainted with him.

William Scherzer was unmarried. He was of a kind and gentle disposition, quiet and modest in demeanor, and he will live in the fond remembrance of all who knew him. His mind was of a high order, and he was just beginning to reap a liberal return for his knowledge, ability and experience, when death put an end to his career.

THE CONTRIBUTION BOX.

Members of the associated societies, and other persons, are invited to send to the Secretary, for this department of the JOURNAL, such matters of general interest as may come to their notice.

Expansion and Contraction of Masses of Masonry under Changes of Temperature.

A VALUED correspondent in Rochester, N. Y., seeks information on this subject. He writes:

"The subject is of interest in connection with the design of masonry dams, retaining walls for embankments or reservoirs, etc., but its importance seems to have been but faintly recognized by engineers; yet the fact of changes of length, due to variations of temperature, is recognized by mechanics. For instance, the builders of Portland-cement sidewalks insist that in order to avoid cracks, the slabs of concrete prepared by them must not exceed a few feet in dimensions, and these slabs are carefully separated by a joint. Masons, in applying coping on a long wall, often have trouble in devising means for preventing the lifting of the stones in summer by expansion, or the sliding of the coping stones at the ends. Appreciable variations of length in the Washington monument are also recorded, variations due to the action of the sun's rays on its separate faces. In long dock walls and harbor jetties, cracks, not due to any settlement, have appeared, and have been ascribed to contraction of the masonry in winter; and it has been recommended by some designers to provide for such shrinkage cracks by making complete division joints at every few hundred feet in the length of the wall.

"In the long concrete aqueduct of the Vanne Water Supply for Paris, such cracks have also appeared on the sunny side, and a very appreciable convexity on that side has also been reported. Laboratory experiments indicate that appreciable variations in length do actually occur in stone and brick masonry, as well as in concrete.

"The advocates of the new system of combined iron and concrete structures recognize an expansion of concrete and cement mortar, equal to that of the iron, and other instances of the recognized expansion of concrete structures might also be adduced. With regard to masonry, however, either dressed and course, or ordinary rubble, or brickwork, I can find no reliable data, and I am led to believe that the profession, as a rule, wholly disregards this element, and ascribes all cracks in the work to defective foundations or to settlements."

Our correspondent adds that in the Erie Canal aqueduct at Rochester, a handsome structure of limestone ashlar, and about 750 feet in length, running east and west across the river, the leakage on the southern face is very much greater than that on the northern face, indicating a probable action of the kind here suggested.

In the March number of the *Transactions of the American Society of Civil Engineers*, as noted in our Library Department in the March JOURNAL, Mr. C. R. Grimm gives briefly the results of experiments to determine the amount of deflec-

tion of the masonry tower of the new Philadelphia City Hall under changes of temperature, but the rate of expansion is not deduced therefrom.

In the same *Transactions* for November, 1885, Mr. F. Collingwood, now Secretary of the Society, quotes from *Annales des Ponts et Chaussées*, for 1863, some experiments of M. Bouniceau giving the following coefficients of dilatation per degree centigrade:

No. 1.—Portland cement, pure, properly gaged and having set under water	0.0000107
No. 2.—Portland cement-mortar, containing 1 volume cement and 2 volumes silicious sand, as ordinarily used in hydraulic work	0.0000118
No. 3.—Brick masonry, of sandy bricks from Havre or D'Honfleur, and of mortar No. 2, the bricks being placed edgewise	0.0000089
No. 4.—The same as last, with bricks placed lengthwise	0.0000046
No. 5.—Beton, composed of mortar No. 2, and of round silicious pebbles (the proportion af pebbles not given)	0.0000143
No. 6.—Dressed limestone from Ranville	0.0000075
No. 7.— " " " Maladrerie	0.0000089
No. 8.— " granite " Dielette	0.0000079
No. 9.— " marble	0.0000054
No. 10.—Cast plaster of Paris	0.0000166

The Box solicits information from its readers on this, as on all other points of interest.

Park Improvement and Poor-Relief in St. Louis.

The city of St. Louis enjoys one of the finest public parks in the world, a park which covers an area of over two square miles. A stream of water flows through the park, and a number of fishing ponds and small lakes have been constructed. These, however, are not large enough for boating in summer, or for skating in winter. One of the city papers conceived the idea of supplementing a $20,000 fund, which had been secured from a Street Railway Company for the construction of an artificial lake in this park, whenever the city should undertake the work, and, by having the work done at this time, furnish employment to many of the unemployed. Some $15,000 have been raised by public subscription in this way, and this fund is daily increasing, so that now there is a fund of $35,000 in sight for the work. The city council passed an ordinance putting the entire work in the hands of a committee of public-spirited citizens, who were charged with the expenditure of the fund. This committee employed engineers, and had plans prepared, subject to the approval of the city Board of Public Improvements. Work was actively begun about the middle of February. Probably $40,000 or $50,000 will be spent in this way, and a lake secured about half a mile in length, and about eight feet deep. Persons out of employment were required to register, and were notified by mail to report, some 500 or 600 being employed daily. They receive the uniform wages of $1.00 per day. This scheme has met with the hearty approval of all classes of citizens, and it is needless to say that it commends itself particularly to those out of employment.

THE LIBRARY.

It is proposed to notice briefly in this department of the JOURNAL such engineering publications as may find their way to our shelves.

Publishers are requested, in sending works for review, to state the prices of same.

Transition Curve, The — by Offsets and by Deflection Angles. By C. L. Crandall, C. E., Associate Professor of Civil Engineering, Cornell University, New York: John Wiley & Sons, 1893. 64 pages, $6\frac{1}{2}$ by 4 inches. $1.50.

A little work in pocket-book form, with flap, containing not only the theory of the true transition curve, but also tables by which the method can be readily applied in the field.

The numerous illustrations have evidently been prepared with much care by the author, but have hardly received justice at the hands of the engraver.

The true transition curve, as defined by the author, is that in which the curvature increases directly with the distance, and it is claimed that here for the first time have been developed accurate methods holding for large central angles and for both the offset and deflection methods.

Earthwork. Tables for the Computation of Railway and Other—. Computed by C. L. Crandall, C. E., Associate Professor of Civil Engineering, Cornell University. Second Edition. New York: John Wiley & Sons, 1893. 42 pages, 9 by $5\frac{1}{2}$ inches. $1.50.

After giving a brief account and demonstration of the prismoidal formula, the author proceeds to the commoner and approximate one of averaging end areas, in doing which he describes a method for allowing for curvature. Rules are given for three-level and for five-level ground, and for irregular ground surfaces. The work contains two tables, one of triangular prismoids by averaging end areas, and one of prismoidal corrections for such prismoids.

Surveying and Surveying Instruments. By G. A. T. Middleton, Associate of the Royal Institute of British Architects. New York: Macmillan & Co., 1894. 116 pages, 7 by $4\frac{3}{4}$ inches. Illustrated. Price, $1.25.

A little book, dealing concisely with the methods and instruments used in land surveying, as practiced in the British Isles. It is a reprint of articles which have appeared in the columns of the *Building News*. The author acknowledges his indebtedness to certain noted instrument makers for the loan of instruments, and to Usill's Practical Surveying and Stanley's Surveying Instruments for much useful information. The book is illustrated by a number of folding plates, which include representations of the level and of the theodolite.

Catalog of "A. L. A." Library (American Library Association), U. S. Bureau of Education, Washington. Government Printing Office, 1893. 592 pages, 9 by 5 inches.

This volume presents a catalog of the model library of 5,000 volumes selected by experts of the American Library, and forming a part of the exhibit of the Bureau

of Education at the World's Fair. This collection represents as nearly as possible the 5,000 books which a new library should first obtain for its collection. Many States have laws permitting the establishment of public libraries in cities and towns, and the support thereof by taxation, and it is believed, therefore, that this Bulletin of the Bureau of Education will be of great value in many cases where such libraries are inaugurated. Besides presenting this desirable list of books, the catalog illustrates at the same time two very complete systems of classification, and it is claimed that in this respect it is the most instructive volume yet printed on the subject of libraries.

Drawbridges Having Two Equal Arms, Maximum Stresses in —. By Malverd A. Howe, C. E., Professor of Civil Engineering, Rose Polytechnic Institute, Terre Haute, Indiana, 1894. 17 pages, 7 by 4 inches. Single copies, 25 cents each ; 10 copies, 20 cents each, postpaid.

In this little volume, reprinted from *Engineering Mechanics*, of Philadelphia, the author presents formulas, tables and a diagram, arranged with special reference to their utility in determining with the least possible labor the maximum stresses in drawbridges. The formulas and the diagram are based upon the theory of three moments, the approximate correctness of which is assumed, and they neglect the effect of any change in the elevation of the supports after the erection of the bridge, separate formulas for this being given in the appendix.

The work is based upon a paper read before the Engineers' Club of St. Louis.

Society Proceedings.

The Engineer. *Year-book of the Engineering Society of the School of Mines, Columbia College*, 1893–94. New York, 1894. This handsome bound volume, with its 86 large pages thoroughly illustrated, and with its 102 pages of advertisements (the despair of needy editors), contains a large number of short but interesting papers, among which we note : " The New Croton Aqueduct," by Edwin H. Messiter, illustrated only by two cross-sections of the tunnel; " A Description of the Topographic Work of the United States Geological Survey," by Gerald F. Sherman (no illustrations); a series of six brief committee reports upon as many different features of the Bethlehem Iron Works; an illustrated account of different forms of cut-off apparatus seen at the World's Fair, by William Y. Westervelt; a valuable illustrated lecture on Bridge Repairs, by W. B. Parsons, C. E.; and a description of the Pennsylvania Railroad Drawbridge over the Hackensack River, by H. Pinkham.

Journal of the Association of Engineering Societies, Vol. XIII, No. 5, May, 1894.

A. Gottlieb

ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881.

VOL. XIII. MAY, 1894. No. 5.

ABRAHAM GOTTLIEB.

A MEMOIR.

By C. L. STROBEL, GEO. S. MORISON AND W. M. HUGHES,
Committee of the Western Society of Engineers.

[Read May 2, 1894.]

ABRAHAM GOTTLIEB was born in the village of Taus in Bohemia, Austria, on the 17th of June, 1837. His father was a merchant in Taus, and the son attended the parish school of the village until he was about ten years old. He then went to Pilsen, also in Bohemia, where he entered the gymnasium to prepare himself for the University. He entered the preparatory department of the University of Prague when he was sixteen years old, and graduated from that University at the age of twenty-four. Immediately after graduation he found employment on the construction of the Kaiser Francis Joseph Railroad, and he remained on that railroad until he came to America. On the 16th of February, 1866, he was married to Rose Pollak.

Mr. Gottlieb came to America in June, 1866, and located in Chicago. His first employment was with Mr. August Bauer, an architect, with whom he remained for a few months. At that time Mr. L. B. Boomer was generally regarded as the most prominent bridge contractor in the West. In 1870 Mr. Boomer united his business with that of Messrs. Boyington & Rust, forming a corporation under the name of the American Bridge Company. On leaving Mr. Bauer in 1866, Mr. Gottlieb entered the employ of Mr. Boomer, and, on the organization of the American Bridge Company, he was made its Chief Engineer.

In 1873 Mr. Gottlieb left the American Bridge Company, and, remaining in Chicago, became the western agent of the Keystone Bridge Company. Four years later he succeeded Mr. J. H. Linville as President of the Keystone Bridge Company and removed his residence to Pittsburg. He continued to hold this important position for more than seven years, when, in December, 1884, he resigned the presidency and returned to Chicago. His connection with the Keystone Bridge Company covered a period of eleven years, a period probably marked by greater advances in the manufacture of bridge superstructure than any equal period before or since, and during this time the position of the Keystone Bridge Company was at least equal to that of any similar organization in the world. Among the more important works built by the Keystone Bridge Company during Mr. Gottlieb's presidency, there may be named the metal work of the following bridges: the bridge across the Susquehanna at Havre de Grace for the Baltimore & Ohio R. R.; the channel spans of the bridge across the Missouri at Plattsmouth for the Chicago, Burlington & Quincy R. R.; the bridge across the Missouri River at Blair Crossing, Nebraska; the bridge across the Monongahela at Pittsburg for the Pittsburg, Cincinnati & St. Louis Ry.; the Madison Avenue Bridge across the Harlem River in New York City; several miles of bridges and viaducts on the Cincinnati Southern Ry.; the original train-shed for the Broad Street Station in Philadelphia for the Pennsylvania R. R.; and a portion of the Sixth Avenue Elevated Railroad in New York City. A somewhat unique structure, built also under his special direction, was the Mining Pavilion erected for the Mexican Government at the New Orleans International Exposition, the details of which were a careful adaptation of the glories of the Alhambra.

While with the American Bridge Company one of Mr. Gottlieb's associates was Mr. Hemberle. About the time of Mr. Gottlieb's return to Chicago, Mr. Hemberle left America. He had established a contracting business under the firm name of E. Hemberle & Co., and Mr. Gottlieb succeeded to that business under the firm name of A. Gottlieb & Co. In connection with his contract work he became consulting engineer and western agent of the Edge Moor Bridge Works. Among the contracts which his firm carried through may be mentioned the iron work for the Masonic Temple and the Tattersall horse exhibition building, and for the Administration building and the Fine Arts building at the World's Fair.

Mr. Gottlieb was the first Chief Engineer of the World's Columbian Exposition, and while the organization of that exposition did not give him that independence of action which might have been accorded under other conditions, a large part of the construction work was planned by him. The restrictions of his authority, however, led to his resignation after somewhat more than a year of active work.

Mr. Gottlieb became a member of the American Society of Civil Engineers September 4, 1872. He was elected a director of that society in January, 1892, and he held this office at the time of his death. He was one of the incorporators of the Engineers' Society of Western Pennsylvania, organized in Pittsburg in 1880; and was president of this society for two years, having been elected in 1882 and again in 1883. In 1878 Mr. Gottlieb became a member of the Civil Engineers' Club of the Northwest, which was subsequently reorganized as the Western Society of Engineers. He was president of this society for the year 1888.

On the afternoon of Friday, February 9, 1894, Mr. Gottlieb called at the office of the Illinois Steel Company in the Rookery, Chicago. On the completion of his business he took the elevator and came to the ground floor. On leaving the elevator he suddenly fell unconscious, and died before medical aid could reach him. His funeral took place on the following Sunday and he was buried in Rose Hill Cemetery.

Mr. Gottlieb leaves a widow and seven children; four daughters, two of whom are married, and three sons, one of whom is of age. He was throughout his life an earnest, careful, conscientious man. He represented in himself many of the best traits of that untiring race which, besides its other gifts to humanity, has contributed some of our best engineers.

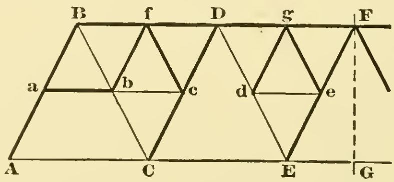
A NEW TYPE OF TRUSS.

By H. F. Coleman, Corresponding Member of the Civil Engineers' Club of Cleveland.

[Read January 9, 1894.]

The object of the writer in presenting for discussion this evening a new form of bridge truss is to ascertain the soundness of certain very severe criticisms made upon the design.

Three spans of this style of truss have already been erected, and three more are about to be erected, by the firm which the writer represents.



The question is: Should the last three spans, which have been taken to illustrate the case, be erected as at present intended, or should some radically different type of truss be substituted? The bridge in question is to be a double-deck bridge to carry coal trains consisting of larry cars pulled by a pony engine or by a common switching engine, which will pass over the top quite frequently, or a few freight cars which will be pulled through the bridge quite infrequently. A single engine may occasionally be transferred from one side of the river to the other, either through the bridge or across its top. The purchaser states that local conditions will prevent the loading of both tracks at the same time, and the writer has made his calculations accordingly.

The larry cars, when forming a continuous train and when loaded to their fullest capacity, will weigh rather less than 2,500 pounds per foot per track. A moving load of 3,000 pounds per foot, run on either the upper or the lower track, has been assumed in calculating the live-load stresses. In addition, a single engine of the consolidated pattern, weighing 87½ tons and concentrating 100,000 pounds on a wheel base of 15 feet, is supposed to run across the structure independently, either above or below, and wherever the stresses thus produced exceed those produced by the uniform live load of 3,000 pounds, they are used in proportioning. The material to be used is open-hearth steel running from 58,000 to 66,000 pounds ultimate strength per square inch. The allowable unit stresses assumed are as follows:

For recurring stresses of like kind:

$$\text{for compression; } + 7{,}500\left(1 + \frac{\text{constant uniform stress}}{\text{maximum total stress in piece}}\right)$$

$$\text{for tension; } - 8{,}000\left(1 + \frac{\text{constant uniform stress}}{\text{maximum total stress in piece}}\right)$$

For alternating stresses:

$$+ 7{,}500\left(1 - \frac{\text{maximum stress of lesser kind}}{\text{2 max. stress of greater kind}}\right)$$

$$- 8{,}000\left(1 - \frac{\text{maximum stress of lesser kind}}{\text{2 max. stress of greater kind}}\right)$$

For pieces in compression the "allowable" stresses given above are reduced by the usual formulas.

The truss, as indicated on the accompanying diagram, is a simple triangular truss in which the top chord segments, instead of being broken by vertical struts, as usual, are broken by triangular sub-struts.

These sub-triangles also break both the main ties and the main struts into two lengths, producing shorter and more rigid members, and, under certain conditions, a lighter structure.

This form of truss was intended primarily for use as a deck bridge only, and the question of using the structure as a deck and through bridge was an after-consideration, but the general design was not altered, for it was believed that even when so used the structure was as rigid as any.

The trusses are to be built of plates and angles, with riveted connections.

The upper flanges on the bottom chord segments are supposed to resist bending or buckling only, and they also act as seats for the cross ties.

The two criticisms most generally urged are that the top chord panels are divided, while the bottom panels are full length, and that the members are redundant, so that it is impossible to compute the stresses in them. The former seems to be considered quite a serious objection.

The dimensions of the truss and of its members, and the stresses in the latter, are given on the following page.

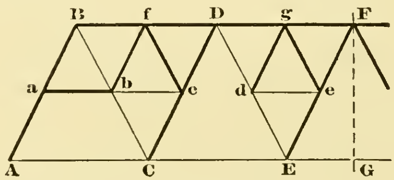
DIMENSIONS.

Span, 105 ft.; 5 panels, 21 feet each.
Depth, 20 ft 6 inches.

Upper chord,	*B D, D F,*	1 cover plate $14 \times \frac{5}{16}$ 1 web plate $21 \times \frac{1}{2}$ 2 angles $5 \times 3\frac{1}{2} \times \frac{3}{8}$	=21 square inches.

	A C,	*C E,*	*E G,*
Lower chord,	2 angles $3 \times 3 \times \frac{5}{16}$	2 angles $3 \times 3 \times \frac{3}{8}$	2 angles $3 \times 3 \times \frac{7}{16}$
	1 plate $26 \times \frac{1}{2}$	1 plate $26 \times \frac{1}{2}$	1 plate $26 \times \frac{1}{2}$
	2 angles $5 \times 3\frac{1}{2} \times \frac{7}{16}$	2 angles $5 \times 3\frac{1}{2} \times \frac{7}{16}$	2 angles $5 \times 3\frac{1}{2} \times \frac{5}{16}$

Main struts,	*A B,*	1 cover plate $14 \times \frac{3}{8}$ 2 angles $6 \times 6 \times \frac{7}{16}$	=15.4 square inches.
	C D,	2 angles $6 \times 4 \times \frac{7}{16}$	= 10 2 square inches.
	E F,	2 " $6 \times 6 \times \frac{7}{16}$	= 8.5 "
Main ties,	*B C,*	2 " $6 \times 6 \times \frac{1}{2}$	= 9.7 "
	D E,	2 " $6 \times 4 \times \frac{3}{8}$	= 6.5 "
Sub-struts and sub-ties,		2 " $3\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$	"



STRESSES.

(+ Compressive. — Tensile.)

Upper chord.

$\frac{3}{4}$ bending moment = 356,000 inch-pounds.

	Dead Load.	Live Load.
B D,	+ 35,500 lbs.	+ 68,700 lbs.
D F,	+ 52,700 "	+ 101,000 lbs.

Lower chord.

$\frac{3}{4}$ bending moment = 1,280,000 inch-pounds.

		Dead Load.	Live Load.
	A C,	— 19,400 lbs.	— 40,400 lbs.
	C E,	— 45,200 "	— 89,000 "
	E G,	— 53,800 "	— 105,000 "
Main struts,	*A B,*	+ 42,400 "	+ 88,500 "
	C D,	+ 23,600 "	+ 56,600 "
	E F,	+ 4,700 "	+ 33,000 lbs. — 18,400 "
Main ties,	*B C,*	— 35,300 "	— 70,800 lbs.
	D E,	— 16,500 "	— 42,500 "
Sub-strut,	*b f,*	+ 2,400 "	+ 14,700 "

DISCUSSION.

Mr. Ludwig Herman.—Are the inclined members of the truss subject to compressive strains only?

Mr. Coleman.—No sir; part of it is for tensile strain, and part for compressive strain, and part for bending strain.

Mr. F. C. Osborn.—In regard to the first objection, viz.: that the top chord is divided while the bottom chord is not, it seems to me that this is a matter in the discretion of the designer and dependent somewhat upon the local conditions. It would have been a comparatively easy matter to provide a vertical suspender from the main top chord panel points to the middle of the bottom chord panels, and the designer no doubt considered this feature.

In regard to the alleged *ambiguity*, I do not see that it exists. I think the truss is as susceptible of calculation as any truss we have.

No matter what the loading me be, the reaction at A may be readily obtained by means of the law of the lever. Having this reaction, the stresses in AB and AC may be readily obtained. The stress in Bf may be obtained by taking moments about C and dividing by the depth of the truss. The stress in fD may be obtained in the same manner, and since the point C about which moments must be taken is the same for Bf and for fD the stresses in both members must be the same. This proves also that the stresses in bf and fc are equal. Of the five forces acting at C, we know three and can therefore readily determine the other two, viz.: the stresses in bf and fc. Of the four forces acting at B, we know three and can, therefore, determine the remaining one, viz.: the stress in Bb. Of the four forces acting at b we know two, Bb and bf, and can, therefore, determine the other two, bC and bc. Having bc and Ac, we can determine the stresses in the two other members meeting at C, viz.: Cc and CE. We have now three of the stresses which meet at c, and we can therefore readily obtain the fourth one, the stress in cD. We now have all the stresses from A to D, and it must be apparent that the same method may be applied to the portion of the truss included between D and the center of the bridge.

The design is simply a triangular truss with triangular sub-trussing; it contains no redundant members and the stresses are not ambiguous.

Mr. W. H. Searles.—I would offer simply one suggestion. The objection to the form seems to be not so much in the side elevation of the truss, as in the sway bracing. If the bridge is used entirely as a through bridge, we have plenty of room overhead for sway bracing to keep the trusses vertical. In a deck bridge we have the entire cross-section for sway bracing. In a deck-and-through bridge, sway bracing must at any rate be kept out of the way of the trains supported on the lower chord.

This requirement, together with the fact that all the members are inclined, makes the sway bracing a little difficult to secure so satisfactorily as if that were not the case. I admit that the question of loading is not the question before us. Yet, as I understand the author, this truss, originally designed for a deck bridge, is now put to the further service of a through bridge with perhaps no other change in the general design than that of keeping the sway bracing out of the way. I agree with the last speaker that the bridge can be constructed so as to form a safe structure, and that the strains can be definitely determined.

Mr. Coleman.—Mr. Searles' objection as to sway bracing can be applied to any truss that is used both as a through and a deck bridge. We depend almost entirely on the portal brace, which runs down from the top about six feet, and up from the bottom five feet.

Mr. Herman.—It appears to me that where more than three members meet at one point, it would be rather difficult to determine the exact strain on each. Theoretically it can be done, but in practice it is not reliable to assume that members under such conditions will divide the load and each take up a definite part of the strain, especially as some members are at the same time subject to compressive and to transverse strains.

Mr. Coleman.—A graphical diagram will check out just as it will with any other truss. It is a perfect diagram for a uniform load.

Mr. Herman.—The strain will generally take the shortest way to its final point. Some bridges, built in this country, had arches in addition to their trusses, and it was thought that the arch would carry one half the load and the truss the other half, but experience showed that either the truss or the arch carried the entire load. Hence each would have to be sufficiently strong to carry the entire load. If you have more than three members diverging from one point it will be hard to say which one carries the load and which carries none.

Mr. Osborn.—That is a different problem altogether.

Mr. Coleman.—If five members meet at a point and the stresses in three of them are known, certainly the two remaining stresses can be determined. And, in general, no matter how many forces meet at a point, if all but two are known, and if the directions of these two are known, then these two can be easily and accurately determined.

I beg to submit the following letter received from Prof. A. Jay Du Bois.

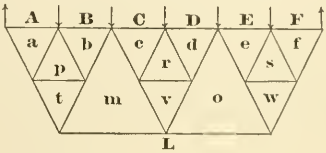
New Haven, Conn., January 16, 1894.

Mr. Henry F. Coleman.

Dear Sir:—I shall confine myself to the single question, *whether your sketch shows redundant members.*

I have no hesitation in saying, upon a moment's inspection, that there *are no redundant members.*

The simple criterion (see theory of strains) is, that the equation, $m = 2n - 3$, shall be satisfied, in which m is the number of members and n the number of apices. In this case $n = 26$ and $m = 49$. Hence $m = 2n - 3$, and, since the criterion is satisfied, there are no redundant members. The difficulty is only apparent. In this sketch it is evident that the reactions LA and LF can be determined for any loading.



Starting at the left we can then determine Aa and La. It would now appear impossible to go further, and this is perhaps why it has been wrongly supposed that there are redundant members. I am surprised that any one should make such an objection after careful examination; for it is evident that if we make a section cutting Bb, bm and mL, we can calculate Bb by moments, taking the point of moments at the first lower apex. We have then Aa, AB and Bb known, and can find ap and pb. Since now we know La and ap, we can find pt and Lt.

Again, knowing Lt, we can find tm and Lm.

Again, knowing pt and tm, we can find pb and bm.

Your graphic diagram gives these quantities at once.

Moreover, the stresses are very easily calculated for any given loading.

Let P_1, P_2, P_3, P_4, P_5 be the apex loads on top, beginning at the left.

θ the angle of the braces with the vertical.

p the panel length.

d the depth of truss.

R the left reaction.

Then

$$Aa = R \tan \theta, \text{ compression.}$$

$$Bb = \frac{Rp}{d}, \text{ compression.}$$

$$ap = \frac{P_1}{2} \sec \theta, \text{ compression.}$$

$$pb = \frac{P_1}{2} \sec \theta, \text{ compression.}$$

$$La = R \sec \theta, \text{ tension.}$$

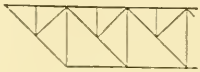
$$Lt = \left(R - \frac{P_1}{2}\right) \sec \theta, \text{ tension.}$$

$$\overline{tm} = \left(R - \frac{P_1}{2}\right) \sec \theta, \text{ compression.}$$

$$\overline{Lm} = \left(R - \frac{P_1}{2}\right) \tan \theta, \text{ tension.}$$

$$\overline{bm} = (R - P_1) \sec \theta, \text{ compression.}$$

Your critics might as well claim that there are redundant members in the "sub-Pratt."



Your truss is simply a "sub-Warren" or "sub-triangular."

Yours truly,

A. J. Du Bois.

THE TEREDO NAVALIS IN BOSTON HARBOR IN 1893.

REMARKS AT THE MEETING OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[December 20, 1893.]

MR. HENRY MANLEY.—Those of us who have had to do with work in Boston harbor know of a little animal which has been found there for many years, eating away woodwork, such as piles, etc., under water. It is called the Limnoria. Its ravages are quite extensive, but by long experience we have become well acquainted with its methods of working and with the proper precautions to be taken. This season, however, we have found a new enemy in our harbor—the Teredo Navalis.

This well-known marine animal works in all the warmer countries of the world, so far as I know, and has done so time out of mind. Its ravages in warm countries are very great. A ship can easily be sunk during a very short visit in those waters.

The Eastern Dredging Company had two large scows built last season in Bath, Me. The hard pine timber was cut somewhere up on the Altamaha River, where it was sawed and whence it was floated down the river and shipped to Bath.

In the spring the scows were brought to Boston, where they were measured. They were taken down to the mouth of the harbor, beyond Boston Light, on or about the 27th of May, for dredging, and were used there during the summer.

In October, or early in November, they began to leak; but by that time the owners had begun to suspect that something serious was the matter, and the one in the worst condition was brought up the harbor. It was found pretty thoroughly bored through by Teredo Navalis, and had to be practically replanked.

Another scow was then brought up, and was found riddled through, though not so badly, by the Teredo.

The samples shown were taken from the planking of the second scow.

The Teredo has for a long time existed on the southern coast of New England; but our harbor, on account of the difference in the temperature of the water, was supposed to be exempt.

This case is almost the first in which they have been found so far north, and is the first in which they have done any appreciable harm.

Some six or seven years ago there was an accident in the yard of the Fitchburg Railroad, where a car was pitched into the water by the giving way of the wharf, and on investigation there was found one pile

in which a passageway had been made by the Teredo. Whence it came or how it happened to get there was never known; but, so far as my knowledge goes, it was the only one that was discovered.

Last summer there was brought to the City Engineer's office a piece of wood which was said to be part of a pile in a bridge over the Saugus River. The sample was thoroughly bored by the Teredo; but I have not yet been able to learn more about it.

There are some curious features in the life and nature of the Teredo. The full-grown animal sometimes attains a length of two or three feet. It enters the wood through a very small hole, and after that passes its life inside, penetrating the wood as it grows; but living, in one sense, a solitary life, as the openings never communicate with each other.

The eggs are formed in the interior of the animal in position, and are fertilized there. They are hatched in the water. While the animal is in the water it passes through two or three different stages of growth, in each of which it assumes a different form. In one stage it is able to swim. In a later stage it has a foot that enables it to cling to any object and to move about to a limited extent. It enters the wood when about as large as the head of a pin. After it makes its entrance into the wood its progress is quite rapid. The four or five-inch plank shown has been torn to pieces during one summer.

The Teredo does not eat the wood, but simply bores it out for a habitation. It has two flues or passages running the whole length of its body and opening out into the salt water. Through one passage it takes in the salt water with the infusoria, etc., which constitute its food, and through the other tube the chips, its own excreta, and everything else it wishes to get rid of, are passed out into the water.

The animal is technically a bivalvular mollusk. Its boring apparatus is a very curious one. The two large shells are not firmly hinged together. Indeed, in the specimen shown they seem to be quite loose from each other; but judging from the amount of work it can do in one season they must, in the living animal, be connected by very powerful muscles.

The instance recorded may be an isolated one, or it may be the beginning of a terrible pest that will cause great trouble for all time to come to those who have charge of submarine woodwork in this harbor.

Among the preventives in common use, covering with copper and creosoting are the most effectual. Creosoting is valuable only for a certain number of years. Before the American Society of Civil Engineers there was recently presented a method of preserving piles by inclosing them in pipes like sewer-pipes; but the Teredo is a pretty tough animal to deal with, and quite different from the Limnoria, which works on the outside of the pile.

You will see that the passage made by the Teredo is lined with a shell-like substance, which it, of course, secretes from the water which it takes in.

You will notice particularly the two grinders. These it must work in some remarkable way, as they are pretty large cutting machines for so small an animal to handle.

Mr. M. M. Tidd.—I well remember encountering these animals thirty years ago, while engaged in the construction of dry-docks. They were then not present in any great numbers; still there were more than we desired. They were brought here in vessels from the East and West Indies. Some of the planking of these vessels was more seriously damaged than any of these specimens. When the vessels came into the docks, and after the water had been pumped down for about an hour, the worms could be seen hanging out of the sides and bottom of the vessel as the water dried away.

Upon striking a smart blow on the side of the vessel with a hammer or a strip of wood, they instantly drew themselves in again out of sight.

Exposure to the air for from twenty-four to thirty-six hours kills them. If a vessel in which they have found lodgment is run into fresh water for three or four days they all perish.

The Teredo is specially fond of Southern pine, and also of oak and cypress. I think it is more fond of hard than of soft woods. The insect is very soft—but little more than a jelly—but he has a terrible tooth and appetite.

I have seen piles eaten entirely away by the Limnoria, which is a very troublesome insect; but I think the Limnoria does less damage to vessels than to piles in wharfing. It seems to prefer clear water and places where the water is in motion.

It is generally supposed that vessels get the Teredo from lying in mud banks about wharves in warm climates at low tide.

Mr. J. P. Frizell.—I think the Teredo works mostly between high and low tide. At least, it does not work above high tide. Hence, in the Gulf of Mexico, where the tides are small, it is extremely destructive to piles, for its operations are then, of course, concentrated upon a short length of the timber. I once built in the Gulf of Mexico a wharf of square cypress piles about ten inches in diameter. In the course of ten months some of these piles were hanging loose, the animals having eaten them entirely off.

I do not quite agree with Mr. Tidd that they come from the mud. In the case referred to the bottom was of pure sand, and there was no mud in the vicinity.

The animal itself has no consistency at all. On examining a piece of timber removed from the water and split, nothing could be seen but a mass of jelly in the holes, and the head, which is of shelly structure and terminates in a boring tool.

After my experience with the cypress piles, I built a wharf with piles of Loblolly pine, which is not considered of any value for sawing. This wood was not touched by the Teredo.

The palmetto, another soft wood much used in the Southern waters, is of a spongy character and is exempt from the ravages of the Teredo.

A good method of preserving wood from the attacks of these animals is to drive small nails into the pile over its entire exposed surface, and then to plaster it all over with cement. To preserve scows we covered them with zinc.

The Teredo, like many other marine insects, has periods of great activity, followed by periods when its operations are almost entirely suspended. This fact must be borne in mind in making deductions as to its habits and preferences. Hagen, in his work entitled " See-, Ufer- und Hafen-Bau," states that the Teredo first made its appearance in wharves and timber work in the ports of Northern Europe in the year 1731, although it had been observed previously in ships coming from Southern ports, and the sheathing of vessels with copper had on that account been practised.

It is somewhat startling to reflect upon the consequences that would ensue if this animal should succeed in overcoming its prejudice against fresh water, or if some equally destructive creature, capable of living in fresh water, should make its appearance. Such an event would be by no means unprecedented, as witness the ravages of the potato bug, which was entirely unknown thirty years ago. In the great Northern lakes, piers, breakwaters, inlets of waterworks, and harbor structures of every kind are built of timber. What enormous losses would result if some fresh-water worm, the counterpart of the Teredo, should make its appearance in these waters!

Prof. G. F. Swain.—It is well known that the Teredo abounds along the southern shores of the Cape, as, for instance, in Narraganset Bay and Taunton River, but Mr. P. S. Archibald, the Chief Engineer of the Intercolonial Railroad, has recently sent me specimens of piles from the northern part of New Brunswick, and they are perfectly riddled by the Teredo, though the animal is much smaller than the Teredo which inhabits the warmer southern waters.

At the time of the Fitchburg railroad accident I looked the matter up pretty carefully and found it was generally supposed that the animal

never came north of Cape Cod. Since then I have heard that this teredo is found along the coast of Maine.

At the time of the Fitchburg accident one of the piles was found to contain one Teredo hole, but no Teredo. We concluded that the hole must have been in the pile when it was brought to Boston, for it had come from the South. The scow described by Mr. Manley, however, was infested with living animals, and as the Teredo will not live out of water it seems as if these animals must have been generated in our harbor. It seems impossible that they could have been brought from the South, although the timber came from Georgia.

Mr. Franklin Pope.—A couple of years ago I was visiting a son of the inventor of the Cook boring bit. The son told me that Mr. Cook, who was a very ardent naturalist, had copied the method of operation of his boring bit from the Teredo. He showed me a specimen of the Teredo which his father had got when he was making a study of the bit.

Mr. F. W. Hodgdon.—I have read that in Holland the Teredo does great damage in certain years, while in other years there were hardly any ravages, and that the reason for this is that in those years when the greatest damage was done the water contains much more salt than in others. The scows which Mr. Manley describes lay right in the mouth of the harbor, where they got the full strength of the sea water.

Mr. Manley.—This may have had some effect. It is clear that the planks were floated down the Altamaha River. It seems to me that it would be easy enough for the Teredo to be brought into Boston Harbor at any time in Southern pine timber. The animals have been brought here in vessels times out of mind, but we have always supposed it was too cold here for them to operate.

The most complete and interesting account of the teredo that I have seen is that of Merrill and Smith ("Invertebrate Animals of Vineyard Sound"). They state that there are at least three species of Teredo, and that another species than the Navalis has been found in Massachusetts Bay, and particularly at Provincetown.

I intend to have these specimens examined by a competent naturalist, to find out whether they are of the Navalis or of some other species. They are bad enough, whatever their species may be.

An isolated case like this is not easy to explain. It may be that the theory of Darwin is being verified, and that this animal is becoming naturalized in these waters, and changing so that he can stand our climate; or, perhaps, there is more salt than usual in the sea this year.

Mr. L. F. Cutter.—In the summer of 1891 the culvert under Bennington Street was cut into for the purpose of building a sewer, and many of these worms were found in the woodwork. They looked just like the specimen shown this evening, They were not Limnoria, for they worked inside of the wood.

Mr. Tidd.—In the sixties I had occasion to work on the Erie basin, and we were troubled with these animals there. In making surveys for timber work in Halifax harbor, I found that place also infested with them, and worse than I had ever seen before, but they were very different from the specimen shown this evening.

Mr. Manley.—I think that neither the Teredo nor the Limnoria works below the surface of the mud, for this animal must have an outlet into the open sea water.

IMPROVEMENT OF GRADES AND ALINEMENT vs. INCREASE IN WEIGHTS OF LOCOMOTIVES.

By Henry C. Thompson, Member of Civil Engineers' Club of Cleveland, Ohio.

[Read February 13, 1894.]

During recent years the natural growth of our country and the consequent construction of competing lines has forced upon our railroad managers a departure from old-time methods of handling freight.

Such departure has required either an improvement of grades and alinement, or an increase in the weight of locomotives to enable them to haul the increased loads over the existing steep grades and sharp curves.

As a rule, our railroad managers have leaned rather to the latter solution of the difficulty, and exceedingly heavy locomotives have thus been introduced on many of our railroads. It is the object of the present paper to inquire whether this is the wiser course, and whether an improvement of grades and alinement would not have been in the end a more economical solution of the question.

In the early days of our railroads, while the country which they penetrated was still in an undeveloped condition, it was naturally the object of the projectors of a railroad to get it constructed as rapidly and with as little outlay as possible, and those most nearly concerned were interested rather in the profits to be derived from the opening up of new territory than in those to accrue directly from the operation of the railroad. Hence, it is not surprising or reprehensible that on these earlier lines heavy grades and curvature are very commonly found, but it by no means follows that such practice is to be commended on lines constructed now in thickly settled parts of the country, where the trade has not to be developed, but is already waiting for the roads.

Inasmuch as the resistance due to curvature may be equated by assuming an equivalent grade, we may confine our attention to the question of the reduction of grades.

Railroads constructed for light traffic, and hence operated with light power, must be strengthened in order to carry a heavier traffic, and, at the same time, it would be necessary either to reduce the grade or to increase the weight of the locomotives. If the latter course is pursued a non-productive weight of locomotive must be carried over the levels and low grades, or else relays of power would have to be used at the grades.

An increase in the weight of locomotives of course involves a cor-

responding increase in the weights of the rails and joint fastenings, in the number of cross-ties and in the strength of the ballast, although the construction of the subgrade might not be affected. Expenses for repairs would, of course, also be increased.

Other things being equal, the cost of hauling a ton of freight over a mile with 50 feet rise will exceed that of hauling it over a level mile, by the cost of the work which would be required to raise a ton 50 feet vertically. In railroading this means an increase in the size and weight of the locomotive, with a corresponding increase in the expenditure for steam, fuel, oil, etc. It, of course, amounts to the same thing in the end if we reduce the loads in order to be able to surmount the grades with a light locomotive, for this would necessarily involve an increase in the number of trains run, and thus entail a loss by reducing the capacity of the railroad for traffic.

An increase in the weight of locomotives also necessarily involves a strengthening, or a renewal, of the bridges on the line.

Let us compare two single-track railroads, each 100 miles long, with 1,600 feet of bridging in spans varying from 70 to 145 feet (shorter spans not considered), and each having a capacity of 60 trains per 24 hours. One of these railroads has a maximum grade of 35 feet per mile and is laid with steel rails weighing 70 pounds per yard. The other has maximum grades of 50 feet to the mile, and is laid with 90-pound steel rails. The writer believes that the weights of rails above named are for economical reasons proper for the conditions assumed.

In comparing these two roads we shall neglect the extra cost of the maintenance of the subway in the second case and the extra cost of running the locomotives, and shall assume that the cost of repairs to the locomotives will be the same in both cases.

We shall also confine our attention to the operations of freight trains, as these, strictly speaking, govern the business of a railroad.

We will assume that in each case a train consists of 35 cars, each weighing 12 tons and loaded with 20 tons of freight, making in all 32 tons per car, or considerably more than the average load in a mixed traffic. The total weight of our train is thus 1,120 tons.

To haul such trains properly we shall require, in the first case, a locomotive and tender weighing together 86 tons, the engine alone weighing 108,000 pounds, with 96,000 pounds on the drivers; in the second case a locomotive and tender of 101 tons, engine alone 134,000 pounds with 120,000 pounds on the drivers, both engines being of the consolidation type.

Assuming the cost of the locomotive, without the tender, at 7 cents per pound, the light locomotive would cost $7,560 and the heavy one $9,380, the difference being $1,820, and the average cost of the two engines, $8,470.

The cost of keeping in good repair a locomotive in active service averages $5.00 per day, or $1,825 per year. In five years this amounts to $9,125, or more than the average cost of the two locomotives in question. We may say, therefore, that a locomotive is renewed every five years.

Neglecting the cost of repairs of the engines, but considering only the difference of $1,820 in their first cost, we have an excess of $5,460 per engine as representing fifteen years' work, and this, on sixty locomotives, would amount to $327,600.

Experience has pretty well established that the practical life of a steel rail in main track is about 7.5 years. This being the case the rails would require renewal once in fifteen years, assuming that they are new when laid.

A 90-pound rail will weigh $141\frac{3}{7}$ tons per mile of track, and a 70-pound rail 110 tons, and this will make a difference in favor of the lighter grades of 3,143 tons on a road 100 miles long. This, at $24 per ton, amounts to $75,432, which may properly be considered as additional capital invested.

At the end of $7\frac{1}{2}$ years we should have, allowing for loss in weight, 3,000 tons of scrap, worth about $27,000, as an off-set in favor of the road with the heavier grades.

At the end of fifteen years we should then have

Excess of first cost of 100 miles 90-pound rail over 70-pound rail	$75,432 00	
Fifteen years' interest on same	56,574 00	
Excess of cost of renewal of 100 miles 90-pound rail over the 70-pound rail at the end of $7\frac{1}{2}$ years	75,432 00	
$7\frac{1}{2}$ years' interest on same	28,287 00	
		$235,725 00
Deducting the proceeds from two sales of scrap		54,000 00
We have left		$181,725 00

as the net excess of expenditure for the heavy rail in fifteen years.

The required increase in the weight of bridges, for the 1,600 feet assumed, would amount to about 80,000 pounds, which at four cents per pound would cost $3,200, the interest upon which, at 5 per cent., would be $160 per annum, or $2,400 in fifteen years.

Summing up, then, we find that in fifteen years the net excess of cost of the line with heavy grades over that with lighter grades will be:

For rail	$181,725 00
For locomotives	327,600 00
For bridges	2,400 00
Total	$511,725 00

or an average of $34,115 per annum, which would represent a capital of $682,300.

Assuming average conditions as to location, we may suppose that not more than one-half of the assumed length of 100 miles would require any material reduction of grades, so that the $682,300 would be applied over a length of not more than fifty miles. Again, we may reasonably assume that the material taken out in the excavations would suffice for the embankments and this would further reduce the distance to twenty-five miles, so that $27,292 per mile would be available for the improvement of grades.

The foregoing figures indicate that it is true economy, in providing for increase of traffic, to improve the grades of a road rather than to increase the weight of its locomotives; for, although the cost of the improvement is the same in either case, we see that, at the end of the fifteen years assumed, the improvements in the grades remain as a permanent betterment for all time, while the expenditure on increasing the weights of the locomotives must be repeated every fifteen years.

If, now, we compare a road with a maximum grade of 35 feet per mile with one having the not uncommon maximum of 65 feet per mile, we find that in the latter case we should require a locomotive and tender weighing 123 tons, or 166,000 pounds, for the engine alone, with 150,000 pounds on the drivers, to haul the given train; and this, of course, would largely increase the excess above that found by the foregoing estimate.

In any given case the engineer should first determine, from a correct profile of the line, the weight of the locomotive required to haul the given load with such ease that it can be reasonably depended upon to make the schedule time. He should then so design the revision of the grades that the cost of such revision shall equal that which, if the grades were left unchanged, would be required by the necessary increase in the weight of the locomotives.

Cases frequently occur where it is impossible to effect a satisfactory revision of the grades at a reasonable cost, or where commercial considerations and the business advantages of an existing location render such revision inadvisable. In such cases it is better to use helpers, of about the same capacity as that of the road engines, rather than to employ excessively heavy engines on the steep grades; for the light helpers are available upon any part of the system, whereas the heavy engines cannot be advantageously employed except upon the limited stretches for which they are designed. The use of helpers, however, obviously necessitates the construction of a second track on the territory where the helpers are used.

If a heavy grade occurs at a terminal, as is usually the case on

north and south roads terminating on the lake shore, it may be found desirable to construct at the top of the grade a yard in which road trains may fill out their complement of cars.

In discussing this subject we have barely considered the question of speed, assuming that the locomotives have sufficient power to start their trains on the maximum grade without assistance and without the necessity of running at the grade. That the engine should always be sufficiently powerful for this is obvious when we consider that a train is at any time liable to be stopped, as by a danger signal, in the midst of a grade.

The stalling of a freight train on a grade is an expensive luxury in the matter of time, to say nothing of other considerations. Such a stalling, on a busy line, means an interruption to the traffic of the entire line during its continuance, so that on a line moving 30 trains each way daily, or 2½ trains (both ways) per hour, if we assume, as before, that each train has 35 cars with 20 tons each, or 700 tons of freight per train, we have, for one hour's detention, a loss of $2\frac{1}{2} \times 700$, or 1,750 tons, in the handling capacity of the line.

In addition to the foregoing considerations we must bear in mind also the danger to which the operation of heavy grades is necessarily exposed. This, although not reducible to dollars and cents for the purpose of a comparison like the present one, is alone an important argument in favor of the improvement of grades and alinements.

DISCUSSION.

Mr. C. P. Leland.—Do I understand Mr. Thompson to say that the life of a locomotive is 15 years? We figure the life of a locomotive on the Lake Shore road at about 25 years.

Mr. Thompson.—I do not mean to say that your engine is thrown away; but merely that the cost of repairs in five years at $5 per day per engine would buy a new engine. Five dollars per day may be considered a minimum for repairs, some roads show as high as seven dollars.

Mr. Leland.—On a road with 500 locomotives, 25 locomotives, or 5 per cent., would pass out of existence and would require to be replaced by 25 new ones every year.

Mr. Hosea Paul.—I think that many civil engineers are needlessly afraid of heavy locomotives and rolling stock. A mistake of this kind was made some twenty years ago on the Fort Wayne road. The veteran civil engineer who directed its fortunes in those days was so anxious to save his track and bridges that competing roads were soon found to be hauling much greater loads than his road could haul. The early rail-

roads of England, at enormous expense, secured lines nearly level and almost straight, and this practice was to a certain extent repeated in the railroads of Ohio. Many of these were built for double track.

The Cleveland and Pittsburg, for instance, had its bridge abutments prepared for a second track, but for the most part this second track has not been laid. Before incurring considerable expense for reducing grades and changing line, we must look up the improvements that are going on in the mechanic arts, and we may thereby very possibly avoid much of these outlays for construction.

The Lake Shore Company has spent many millions of dollars to reduce very moderate grades. It was done as a measure of economy, and this has no doubt fully justified itself; but even here it might be of interest to institute a comparison between this policy and that of introducing heavier rails, heavier locomotives, more complete signal and block systems, etc.

Many railroads having but a very moderate traffic, have attempted to hew down the face of nature and smooth out its rough spots, but the undertaking has not usually been profitable.

Mr. Thompson.—I think Mr. Paul has misunderstood me. In the early part of the paper I made the remark that some of our earlier roads, for economy in first cost, were constructed with sharp curves and heavy grades, as the traffic was light. I advocated this; and I believe that it was right for those conditions, because those early roads acted as pioneers in opening up the country. Those who built the roads cared little whether they earned anything or not, for the profits were expected to follow the increase in the value of the country developed. As the demand for transportation increases, you must increase your facilities for doing it, either by reducing grades and curvature or by increasing the weight of engines; and I believe that greater attention than is usual should be given to the former method. In ordinary country you will not find more than three or four ruling grades in 100 miles. Suppose you have a 65-feet grade, one of 50 feet, one of 45 feet and one of 35 feet. You must provide your motive power for the heaviest grade, and this gives a great and wasteful excess of power on the levels and lighter grades. A rail lasts somewhat longer on a level than on a grade; but the level requires the same amount of ties and the same ballast. The idea I wish to convey is that while an increase of the power over the practice of 20 or 30 years ago is proper, the excessive increase, bringing in use great engines weighing 112 tons and over, is not economy.

Mr. Paul.—I understand the propriety of disposing of engines so as to bunch them on the heavy grades. That idea came to us from the West, as did also that (which Mr. Thompson condemns) of using short grades of exceptional steepness and overcoming them by a run.

Mr. E. A. Handy (Chief Engineer of the Lake Shore Road).—It is very difficult, perhaps impossible, to lay down rules that shall apply to all roads. Each road must take into account its own physical and financial conditions before it can determine whether it is advisable to reduce its grades. On the Lake Shore Road, the engine that formerly hauled 35 cars to-day hauls 50.

Mr. William C. Jewett.—Many roads are built with as much as 60 per cent. of their line on the maximum grade adopted for the road. In such cases when the grades are long the only remedy is, either to rebuild the road on a new location or to increase the motive power. There is a tendency among engineers to adopt long straight lines at the expense of low grades; curvature in connection with low grades is not objectionable. In determining the maximum grade for a new line recently, one location gave a 0.35 per cent. maximum grade and another a 0.45 per cent. grade, the latter being the shortest and cheapest route. Investigation showed that with the motive power that was to be used the difference in the capacity of the two grades was about four cars per train, or, for the traffic in sight, a difference of one train per day. The lowest grade was consequently adopted as the most economical.

Mr. W. H. Searles.—Many quantities enter into this equation of economy, and we cannot arrive at a final conclusion until we carefully consider them all. It is difficult, therefore, to discuss the question in an open meeting. It must be pored over at the engineer's desk, and after a consideration of various statistics. Still there are a few main points that are pretty well established. One of these is that, other things being equal, a larger locomotive is more economical to the railroad company than a small one. For instance, for a given amount of power distributed among three locomotives the expense is less than if it were distributed among four. The reason lies not only in the capacity of the machine itself, but also in the the number of locomotive and train hands required. But with increase in the power of the locomotive comes the rapid wear of tracks and the necessity of enlarging and strenghtening bridges. Other things being equal, economy is always favored by light grades. If the grades were established at the best rate for the located line, it becomes a serious matter to change that grade on the same line. But in general we must admit that the tendency is toward larger capacity of cars and locomotives, heavier bridges and heavier rails, and it seems that the end is not yet. Undoubtedly there is a limit to the economical increase in weight of locomotives, as there was found to be a limit in steamship practice. Our modern engineers across the water, when they designed the Great Eastern, undertook to jump at a conclusion, to reach at one bound an unprecedented point of economy. Instead of climbing by degrees from one size to another, they built that enormous vessel,

and it was a loss to its successive owners until it was broken up for scrap. So there must be a limit to the size of the locomotive on a given width of track. We are now probably getting somewhere near that limit. It has been well said that the problem is one which must be separately solved in each separate case according to the circumstances of that case. I do not see that we can decide, off hand, a question so intricate as this. The discussion, nevertheless, is pleasant, and very likely profitable, and the figures of the paper, I think, will be valuable as a contribution when we have the opportunity of reading them in print.

The increase in weight and cost of track is not solely due to the use of heavier locomotives. Both freight and passenger cars are built heavier, and of greater capacity, than formerly; and a track sufficient to carry these will, in general, be heavy enough for the locomotive which hauls them. The weight per lineal foot of the heaviest loaded cars is now not much less than that of locomotives, so that in this view the weight of rail required is independent of the maximum grade. The grade limits the length of the train, but does not affect its weight per lineal foot.

Mr. Leland.*—On the freight service of the L. S. and M. S. Ry. there are used: Mogul engines—maximum weight, 59 tons; minimum weight, 40 tons; 10-wheel engines (6 drivers), weighing 49 tons; 8-wheel engines—maximum weight, 54 tons; minimum weight, 30 tons. There are ordinarily 230 engines in freight service. These averaged last year 36,006 miles each.

* These data were kindly furnished, at Mr. Thompson's request, after the reading of the paper.

THE ORIGINAL CONSTRUCTION OF THE BURLINGTON BRIDGE IN 1867–68.

By C. H. Hudson, Member of the Western Society of Engineers.

[Read March 7, 1894.]

The very interesting paper of Mr. Geo. S. Morison, upon the reconstruction of the Burlington Bridge, read before this Society December 6, 1893, recalls to the writer its original construction, of which he had immediate charge, as Resident Engineer, many years since.

Some of the memories thus recalled form the basis of this paper.

An apology may perhaps be considered in order for writing of matters so long gone by, but in view of the placing of the modern, heavy, double-track superstructure upon the old substructure, some description of the methods used in the construction of the old bridge may be found of interest.

As stated by Mr. Morison, this was the first iron bridge across the Mississippi River; the earlier bridges at Rock Island and Clinton having been of wood, except that the draw span of the Clinton Bridge was of iron.

Crib work was used to some extent, in at least one of these, in the foundations and piers.

In the early consideration of the Burlington Bridge, many engineers of experience were consulted. The recommendations then made by some of these gentlemen would to-day be considered very amusing by the members of this Society.

It should be borne in mind, however, that the science of bridge building has made great strides in the last quarter of a century, and that the engineers of that day had to depend very largely on their own judgment and ingenuity. They had fewer precedents for their guidance than has the engineer of to-day, and much less engineering literature was then accessible than is now at the disposal of the engineer.

Mr. Max Hjortsberg, the Chief Engineer, who is undoubtedly remembered with love and professional esteem by many of the older members of this Society, spent much time and thought upon the subject of the proposed construction. His examinations of the river and its surroundings began in 1865. The material of which the river bed was composed, the currents, the probabilities of scour, were all studied, and it was finally decided that it would be practicable and economical to use pile foundations, cutting off the piles near the river bottom.

The question of founding the piers upon large caissons sunk by means of air pressure was discussed; but in the light of borings which had been taken to ascertain the character of the material to be met with, it was believed that while the pneumatic caissons would unquestionably be advisable in the silt bottom found in the Missouri and lower down in the Mississippi River, the bottom at Burlington was of such character that the cuttings met with in the silt could not occur, and, therefore, that these more expensive methods were unnecessary.

Subsequent and much more extensive examinations sustained the conclusions drawn, and the work was completed on substantially the lines originally laid out, although some changes in detail were made in order to overcome certain difficulties, as they presented themselves.

The work of the exact physical location was commenced in January, 1867. Fortunately for the convenience of the work, the river was frozen over, so that exact measurements and accurate locations of centers and pier lines could be made. Cross lines were turned, with range points on the bluffs (several hundred feet high) on the west shore, and upon the bottom lands on the east, two points being always set, and sometimes three, in the low bottom lands, in order to provide against the effect of the spring freshets.

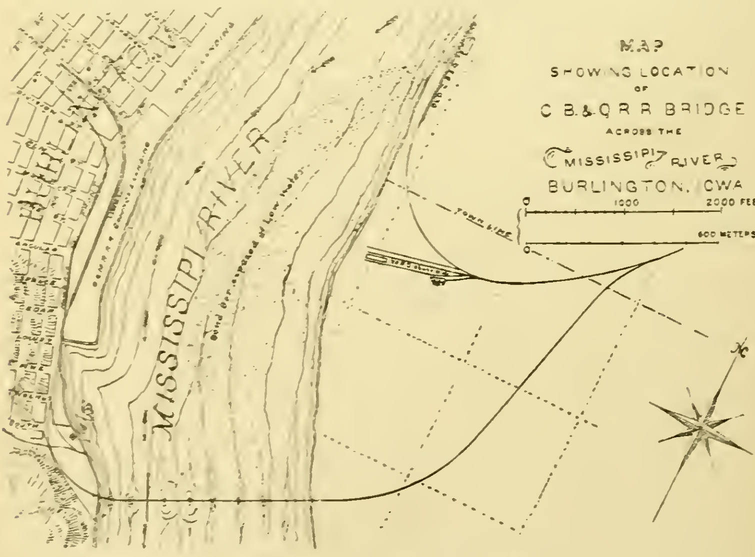


FIG. 1.—PLAN OF LOCATION.

The Mississippi River at Burlington (see plan, Fig. 1) runs nearly due south, curving slightly to the southeast below the city. For some distance above the city, as well as below, the river hugs closely to the

foot of the limestone bluffs, which are here 300 or 400 feet high. The city is located chiefly upon a small plateau at the mouth of Hawkeye Creek, but it has also spread out upon the high ground on the bluffs.

The location selected for the bridge was nearly a mile below the public landing of the city. The river here was about 2,000 feet wide, with the channel on the west side, close to the Iowa shore. East of the river, for seven or eight miles, extended low bottom lands, through which extended many bayous or old channels. In high water this whole bottom was overflowed, and excessive currents obtained in the old channels, as well as in the river proper.

Upon the eastern side of the river proper was a shoal or bar, as shown, extending from the old ferry landing to within a fourth of a mile of the bridge line, and bare at extreme low water. I understand that in later years this has extended very much.

At ordinary stages of the river, the currents were about three miles per hour in the channel and two miles in the shallower part of the river, near the east shore. In high water the velocity increased greatly, and at times reached 4 and 5 miles per hour in the channel, and over 3 miles per hour near the east bank.

During the progress of the work, the velocities and the courses of the currents at various stages of the water, especially in the vicinity of the draw, were repeatedly and accurately observed, and the lines on which the draw fender or protection pier should be built, were thus ascertained.

After the location of the line, in January, and the determination of the spans, some little work was done in the way of driving piles for the easterly piers and preparing for the east abutments; but early in February the ice broke up and a flood followed, driving us from the river for a time. The time was spent in getting material and machinery ready for a vigorous prosecution of the work when the water should fall. By the middle of March it was low enough to enable us to resume work, and it continued to fall until about the last of the month. Early in April it rose again, and it continued high until the middle of August. Early in July it reached its highest point, within 5 feet of the unprecedented high water of 1851. By the middle of September it had fallen to about its normal stage, where it continued until March of the following year (1868). The water then rose rapidly, covering everything, and for two months we were much disturbed.

During February and March, 1867, while unable to work on the bridge proper, we had constructed on the east shore a branch road about a mile long from the main line to the bridge site, laid tracks for stone-yards, gathered material, such as stone and piles, built boats with which to carry on the work, etc. Upon the west side of the river, too, we

constructed half a mile or more of track, to reach the bridge and bring material from the West.

Two powerful steamboats were purhcased, and when the water permitted we were ready with a fleet of flat boats for the handling of material, pile-drivers, etc., the motive power to handle them, and machinery to do the work.

The foundations were put in by our own men, using our own material. Only the masonry and superstructure were built by contract. We were thus enabled to modify our foundation plans at any time, without involving complications.

The east abutment (No. 11, as we numbered them) was of the ordinary wing form, and was built upon piles which were cut off below low water, a cofferdam being made to protect the work from water. The piles were capped and covered with a double thickness of 4-inch planking, put on diagonally, the material being rammed solidly below the caps and under the plank. All of the wood was under extreme low water.

The masonry was laid upon this plank grillage.

The stone for this pier, like much of the other stone used, came from the Lamont quarries, near Chicago. Some stone was procured also from the limestone quarries twenty miles east of Burlington, on the

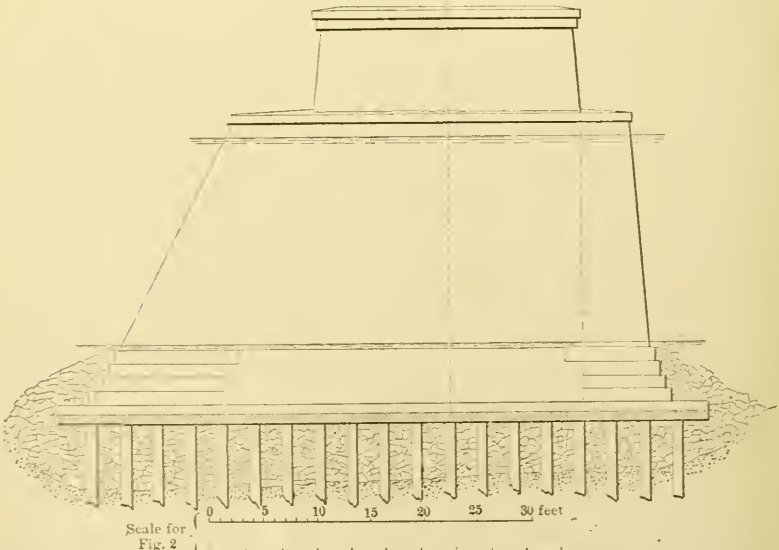


Fig. 2.—Pier No. 6.

C. B. & Q. line, some was brought by boat from the quarries just above Rock Island, and still other stone, used upon the west side of the river, came from Mt. Pleasant, Iowa. The cement used was from Utica, Ill.

The river piers, Fig. 2 (excepting those on each side of the draw, which were 9 feet thick), were 7 x 23 feet at the top, not including the projections of the coping and bridge seats. The square form of pier extended down about 10 feet, with a batter of 1 inch per foot on all sides. Here the length of the pier increased to about 36 feet 10 inches. From this point down the sides and the down-stream end continued to batter 1 inch per foot, and the latter was semicircular in plan. The nose had a batter of 6 inches per foot, and the up-river starling was at the top formed by curved lines, each side being a segment of a circle, with the thickness as a radius. The radius thus increased from the top toward the bottom. The center remained in the plane of its original position, but moved up-stream and toward the nose so that the curve reached the batter line of the nose.

For about 5 feet above the foundations the masonry was laid with about 8 inches off-set in each course, thus obtaining a much broader bearing upon the piles than would otherwise have been obtained.

The piers on each side of the draw were 9 feet wide at top, and 19 feet wide at base, being at the same time 60 feet long, the off-set courses at both ends having been cut off.

The center draw-pier was round, 34 feet in diameter at top, and 44 feet at bottom, with the usual off-set at the bottom, and was built solid. The sides battered 1 inch per foot as in the other piers.

There were under this pier 333 piles, a very large portion of which reached the shale. Under the next pier east were 174 piles, and under the others (except Nos. 1 and 2, at the western end, which rested directly on the shale) from 174 to 133.

It had been intended to cut off the piles as near the bottom of the river as possible, but it was found that as we drove them the currents cut away the sand and enabled us in all cases to cut them at least one foot, and in one case five feet, below the original bottom.

The river bottom at this crossing is composed of sand. The finer particles are at the top, and much coarser ones below. Below the sand is a very hard blue shale. At pier No. 2 the shale was about 5 feet below the surface of the sand, and the latter was very near low water. At pier No. 3 the shale was about 12 feet below the surface of the sand. At the draw-pier the shale was from 22 to 26 feet below the surface of the sand, and continued to slope downward toward the east. We followed it with our borings until it was 70 feet down. From near pier No. 5 eastward we found, from one-third to half-way down from the surface of the sand to the shale, a layer of very coarse cemented sand,

over one foot thick. This was very hard and we had much trouble to bore through it. There were several other layers of the same cemented material from 2 to 6 inches thick, but none so hard as the one first mentioned. It dipped like the shale, but apparently less rapidly. Any one of these layers seemed sufficient to prevent any cutting out by the waters.

When near completion we had some very severe tests which satisfied us that our foundations were absolutely safe against any disturbance of this character.

The piles of pier No. 3 all penetrated the shale from 1 to 2 feet. Those of No. 4, the pivot pier, 333 in number, all went very close to the shale, and at least one-third of them, mostly near the exterior, penetrated it to some extent.

At pier No. 5 we were unable to reach the shale with our piles (174 in number), but they went through the layer of cemented material and averaged about 28 feet in the sand. Of course no other piles reached the shale, but most of them struck one or more layers of the cemented material. Their lengths ranged from 22 to 32 feet, averaging about 28 feet, below the sand. Many very large piles, from 50 to 60 feet long, were used to accomplish this. They were driven with a 3,000-pound drop-hammer.

In order to make the foundations still more secure, the sand was cut out from among and around the piles, by means of jets driven from a powerful pump operated by machinery carried on boats floated above the work. Our streams stirred up the sand and the currents of the river at once carried it away. This, of course, was done after the piles had been cut off. When the sand had thus been cleared away for several feet below the tops of the piles, the space was partly filled with fragments of stone from 4 to 12 inches across. The nozzle of the hose from the pump was then inserted among the stones, and the boiling process which followed washed out the sand. The river currents carried this off as before, and let the stones sink. This process was continued until the stones would sink no more and no sand could be raised. More rock was then thrown in and the whole leveled up even with the top of the piles. Considerable stone was placed outside of the piles, as well as between them, thus aiding still further in the protection from scour. See Fig. 3.

It will be understood, of course, that this submarine work was done by diving crews, and with the usual diving suits. A special boat was used for this work, and the air pumps were driven by steam.

When our masonry was done, large quantities of riprap were thrown around the piers. As the sand washed out, this dropped into its place.

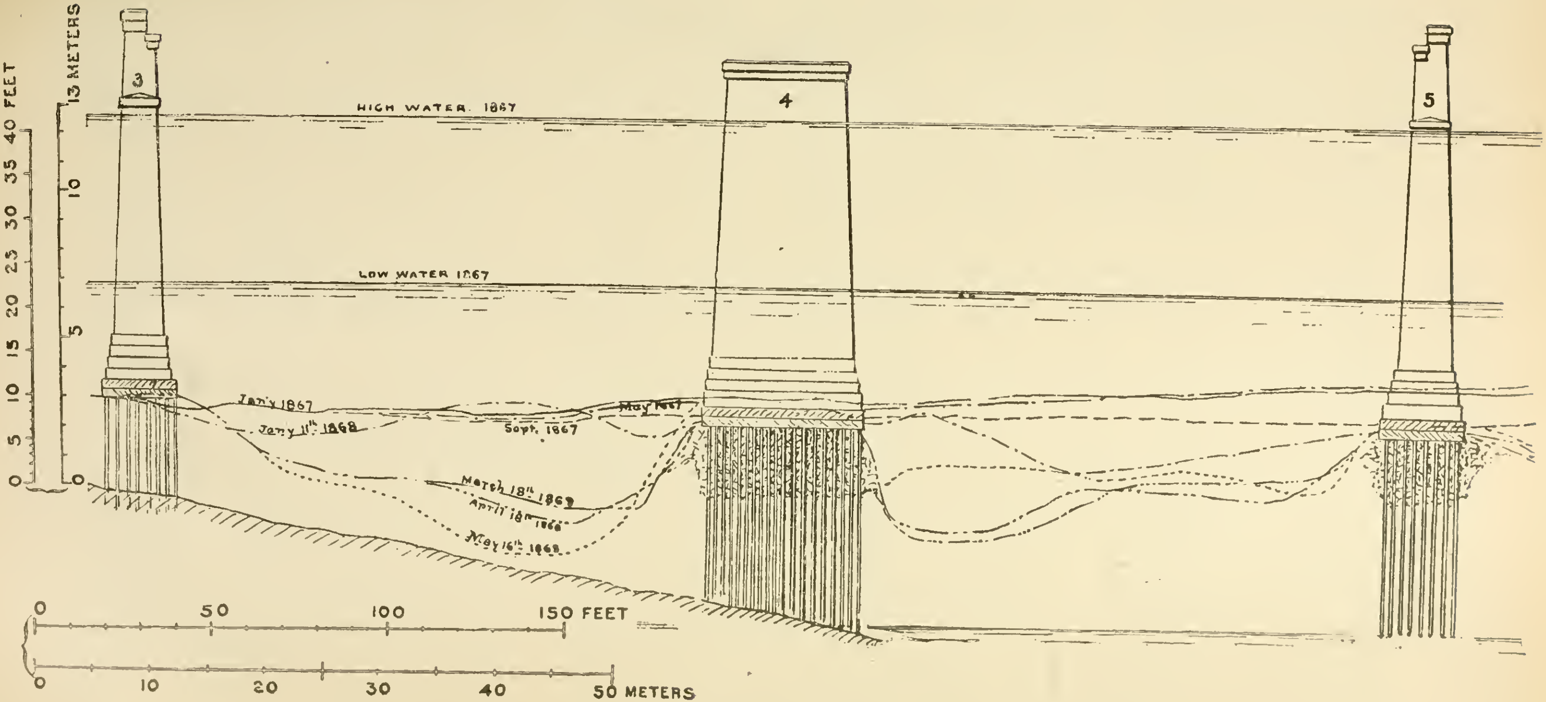


Fig. 3.—Piers of Pivot Span.

In high stages of the river, the bottom was frequently scoured, and the stone settled into the gap. Then as the water fell and as the currents became less swift, sand filled in and over portions of the sunken stone. Each process of this kind tended to make the whole more secure.

The effect of these floods is shown by the profile of the river in Fig. 3, herewith, showing the bottom at various dates: January, 1867; May 15, 1867; September, 1867; January 11, 1868; March 18, 1868; April 18, 1868; May 16, 1868. Very heavy scours are indicated on the profile on each side of the pivot pier in March, 1868.

Many other observations were taken, but these suffice to show the workings of the floods. It was noted that when we commenced to put in piles the scour of the surrounding sand began, and under normal conditions, it increased with the obstructions. In general, if the river was blocked by obstructions, just so much would be cut out elsewhere, and the area of cross-section was thus maintained constant.

The pivot pier was the last one finished. It was completed March 3, 1868. On the 5th the water began to rise, and the ice to break up and move out. The protection pier or fender for the draw had not been built, and there was practically nothing to protect the newly finished pier from the ice, which was running heavily. Much care had been taken in filling, with stone, the spaces between and around the piles in the manner described, but no riprap had yet been put in around the pier. A few days later a heavy ice-gorge some miles above Burlington broke and the great masses of ice came down, filling the whole river. Our temporary pile bridge, extending from pier No. 5 to the eastern shore, caught the ice and practically the whole river east of the draw was closed, forcing the whole volume of water through the draw openings.

On the 13th the water had reached its height, and had carried away 300 feet or more of the temporary pile bridge, letting out so much of the gorge. The energy of our whole force was for some days directed to the working out of the rest of it in order to relieve our works from danger. It was not until the 18th that we were able to measure the bottom and thus to show the form on that date. How nearly the line shown represented it under the greatest pressure we do not know.

Fig. 3 shows the position taken by the stone we had "washed" in around the foundation piles. All tests showed that our pier was unharmed.

We were now enabled to put in riprap much lower than we could have done in any other way, and much of this work was done.

In April there was another rise in the river, and although there was no ice moving, the bottom was cut still lower, as shown by the line of the 28th.

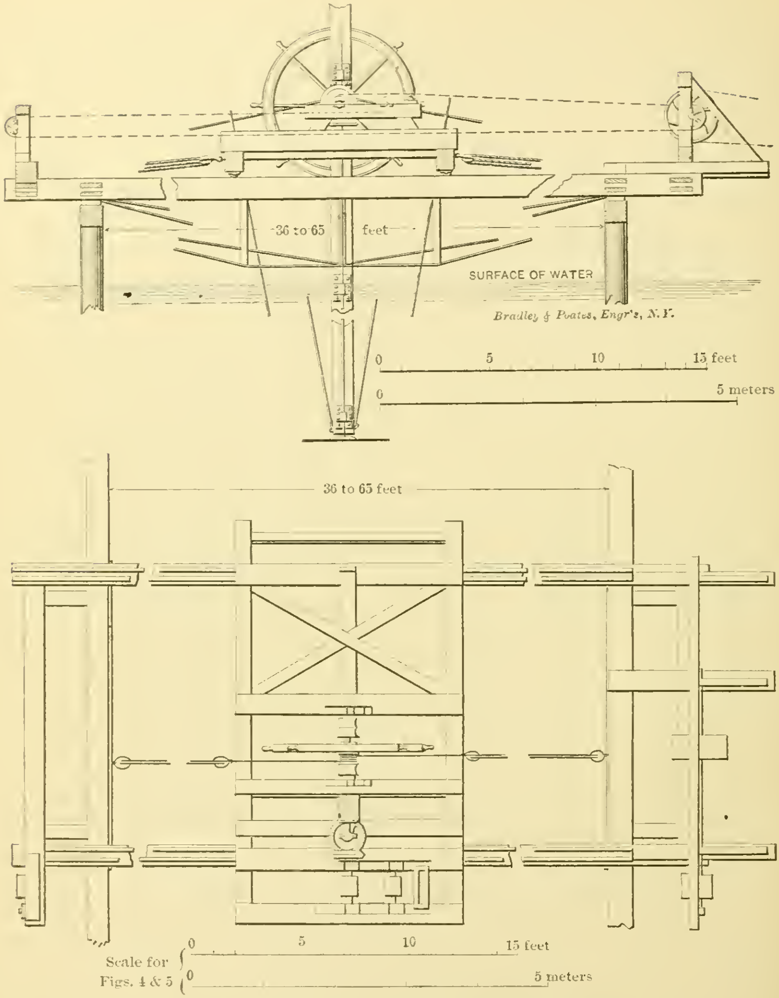
On May 11th the water was up again, above the April flood, but on the 16th, as shown, the east opening of the draw had filled in, while the west opening had cut still deeper, going practically to the shale about midway of the opening. As the water subsided, these holes began to fill in, but as my observations ceased in June I cannot say to what extent this proceeded.

In putting the foundations in the river we used heavy boat pile-drivers, 24 feet beams and 45 feet leads, and machinery heavy enough to handle easily a 3,000-pound hammer. The boats had three "spuds," one on each side, about 10 feet back from the front end, and one in the rear, so that it could be held steadily in place.

It was the custom to drive eight or ten piles in the shape of an inverted V, 100 feet or more up stream from the pier upon which work was to be done. These were usually capped, and a float of timbers was placed upon the up-stream side. The object of the V was twofold—first, to permit the easy handling and swinging of the pile-driver boat; and second, to protect the work from driftwood, rafts running in, etc. One would think that the raftsmen would avoid obstructions, if possible, but that did not seem to be the nature of those driving rafts down the Mississippi in those days. They felt secure with their heavy crafts and they resented the placing of any obstruction in the river. They carried away our works several times without injury to themselves, and we thus learned to strengthen our structure until we thought it was safe. On one occasion a large log raft was tied up for several days a couple of miles above the bridge, in order to strengthen its front end, the crew boasting that they could then destroy our works. But in the intervening time our own works had been strengthened, and when the shock came, one morning, just at daybreak, their raft was broken into many pieces. We were never troubled again in this way.

These Vs also aided us in closing the river above us when the ice began to form. With our steamboat and barges we could, with the aid of lines to Vs on each side, stop the running ice for half an hour or so, and it was then either frozen or gorged so tightly that we had no further trouble. With our boats we kept the ice broken about our work, so that we were not hindered in the delivery of material at the points where it was needed.

Our piles, when driven, were sawed off by machinery (Figs. 4 and 5). On each side of the pier, and a few feet away from it, we drove a row of piles, perhaps 6 or 8 feet apart. These were capped, and upon the cap was placed a traveler 12 feet wide, arranged to be moved from end to end of the pier on these caps. Upon this traveler was another and smaller one, arranged to run upon it and across the pier. This last traveler carried a vertical shaft in a properly braced frame. This



FIGS. 4 AND 5.—PILE-SAWING MACHINE.

shaft carried at its lower end a circular saw about 36 inches in diameter. The shaft could be raised or lowered as required, and was driven by means of a beveled gear from a horizontal shaft on the little traveler. A long belt extended the whole length of the large traveler, around a pulley on this horizontal shaft and another guide pulley, so arranged that the shaft was turned regardless of the position of the little traveler. An engine on a boat alongside the pier was the motive power.

The little traveler was fed across the pier by means of a set of small blocks on each side, and a line which ran around a wheel shaft

like a ship's steering wheel. By this means the traveler could be moved either way, and we could thus cut off a row of piles running one way, and then, by feeding back, cut the next row, the large traveler having been moved back to reach it. In this way 12 or 15 piles were cut off per hour. The efficiency of the saw under water is, of course, very much less than in the air.

After the sawing off of the piles and the filling of the spaces between them with stone, the foundation was ready for the masonry.

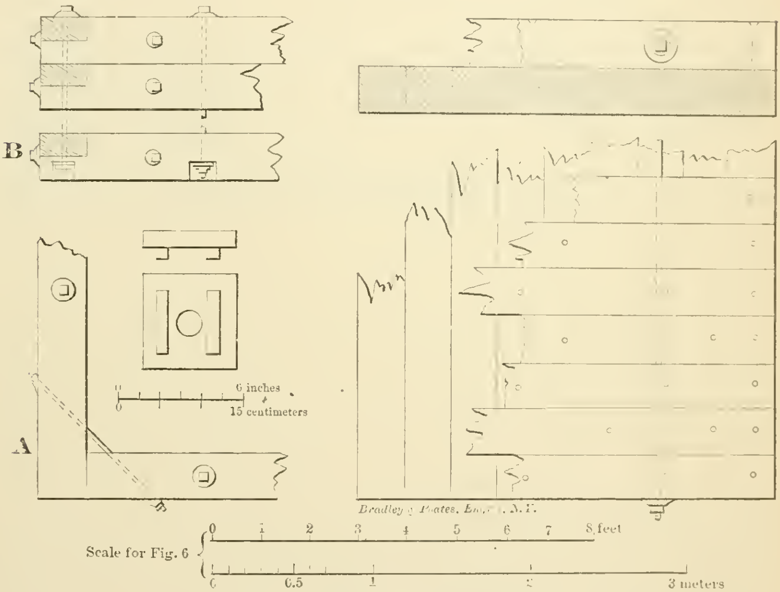


FIG. 6.—DETAILS OF CAISSON.

This was built in floating caissons (Fig. 6), which were constructed of square timber about 12 x 12, dressed on three sides, and all to one size. The floor was of two thicknesses, the lower across the pier and the upper lengthwise of it. The upper course was bolted together with long 1¼-inch rods, running from side to side. The upper course was also drift-bolted to the lower course, the timbers of which were placed close together. Thus the bottom was a solid mass of timber about two feet thick. The sides and ends were of sized square timbers, placed one above the other. At the corners the end and side timbers of each course were halved together and held by ¾-inch bolts passing horizontally through both timbers at an angle of 45°, as shown at *A*.

About eight of these sets of timbers were placed one above the other and then bolted down to the bottom by 1¼-inch bolts, spaced 4

feet apart. The bolts had square heads at the top, and were screwed into nuts set in square washers at the bottom.

The next section, constructed in the same way, was put just above the first. To join two such sections together the nut at the lower end of the bolt of the top section was placed under the top timber of the lower section, as shown at *B*.

The object of this mode of construction was to enable us, by unscrewing the bolts, when the masonry was finished and in place, to remove the timbers forming the sides and ends of the caisson and to use it elsewhere. The side of the caisson could be extended up as high as the depth of water might require. The cracks between the timbers, both in the sides and in the bottom, were calked with oakum and made water-tight.

The bottom and one section were usually put together on land, and the caisson was then launched, and, while floating, carried up to any height required. Staging timbers were then put upon it to carry the travelers and crabs used in handling the stone. The ends of these staging timbers projected out beyond the ends, so that the crab could run over the car or boat when carrying the stone. See Figs. 7 and 8.

The caissons completed were towed to place. The piles upon which the saw machinery ran were furred out so to act as guides after the caisson was in its exact place, and two piles for the same use were put below the caisson and furred out properly, the blocking from the caisson being near the bottom. The masonry was then laid out in proper form upon the bottom of the caisson, and the work of laying stone commenced. It was guided by squaring up from the bottom (or using lines), and not by using levels, for the caisson settled one way and then the other, as the load was increased on either side. The laying of the stone continued until the bottom of the caisson was within two and a half or three feet of the piles, when an examination was made by the divers to ascertain if everything was clear. If so found, a hole was bored through the side of the caisson below the water line and the water was let in, thus slowly sinking the caisson to a bearing on the piles. As soon as such bearing was reached, tests were made as to position. If from any cause the masonry was much out of position, the water was pumped out, and the caisson raised and moved as required. In only one case did we have to raise a caisson after it had settled, and in that case some sand had been deposited on one corner of the foundation to a depth of 6 or 8 inches during the night after an examination and previous to the settling. The caisson was raised and the sand removed, and the caisson again settled into place. The masonry was then completed, using the level in the work. After the completion of the masonry the sides of the caisson were removed at pleasure, as has been explained.

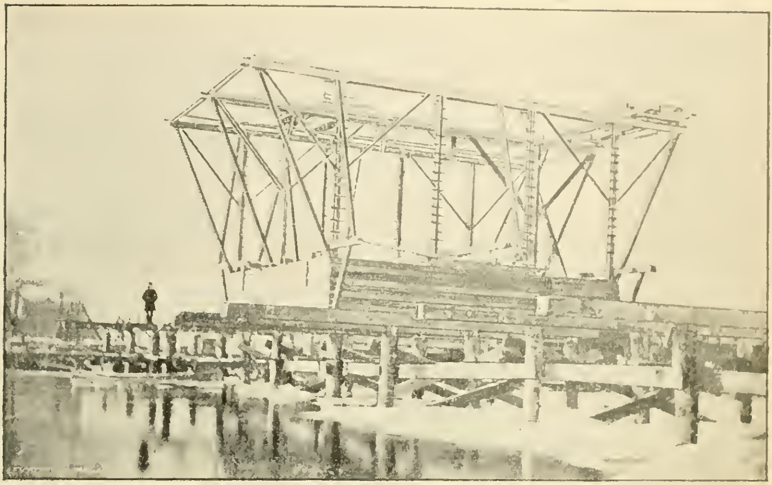


FIG. 7.—CAISSON FOR PIVOT PIER, JANUARY 15, 1868.

Fig. 7, from a photograph taken January 15, 1868, shows the caisson for the pivot pier as it was put in place and before any stone was laid. It shows the open water below the bridge, while among the piles and above the bridge was a solid mass of ice. Piles had been driven for a temporary track to enable us to run stone out upon cars, the stringers not yet being in place.

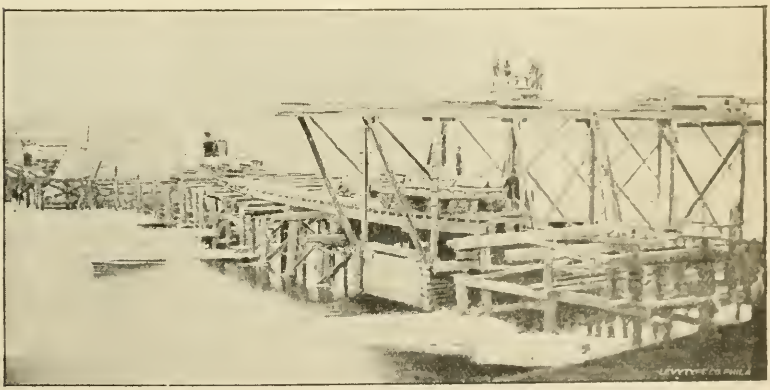


FIG. 8.—CAISSON FOR PIER NO. 6, DECEMBER, 1867.

Fig. 8, from a photograph taken a month earlier, shows the caisson of pier No. 6, well down in the water.

The masonry was rock-face, with joints pitched. No attempt was

made to give a smooth exterior. The face stones were as large and thick as could then be got from the quarry used, but much smaller in every way than the Bedford stone used in the reconstruction. The backing was of large stone, and all the stone was laid in cement, no dry work or grout being allowed. The Utica, Ill., cement used was inferior, of course, to the Portland cement recently used.

As a whole, the masonry was strong and pretty fair. Its quality is vouched for by its being loaded, after its 23 years of previous service, with the new heavy double-track bridge.

The superstructure has been sufficiently described by Mr. Morison.

While it is true that the reconstruction in the form of a double-track bridge cost but about one-third of the original expenditure, it should be borne in mind that work under water costs very much more than work in the air, and that there was practically no subaqueous work in the reconstruction. The amount of masonry in the new work is small compared with that in the old, and the cost of material of all kinds is much less now than it was at that time. Steel rails now cost less than one-third of what iron rails cost then; supplies of all kinds but little more than half of their cost at that time, and labor is consequently reduced in about the same ratio. The superstructure of the new bridge cost between 5 and 6 cents per pound, while that of the old, if my memory serves me right, cost about three times as much.

The currents varied, not only in different parts of the river, and at different stages of the waters, as already stated, but also at different depths; that is, the current at the surface was not the same as that at two, three or four feet below the surface. The courses of the currents varied at different stages of the water.

Our observations further showed that with rising and high water the elevation of the surface at the center was greater than that at the edges by sometimes as much as two inches.

After pier No. 5 had been finished for some time, an examination was made, in order to see to what extent the heads of the piles had indented the under surface of the caisson, built of white pine. It was found that the indentations varied from one-sixteenth to three-thirty-seconds of an inch, and in no case exceeded one-eighth.

Perhaps the most curious thing noted was that the piers—huge masses of solid masonry as they were—were in constant motion. The writer had known of cases where large telescopes, notwithstanding their heavy foundations, had been set trembling by a passing horse, and was curious to know how, if in any way, the flow of the waters would affect these heavy piers. It was only after many attempts that any vibration was detected, and then it was by the use of a very delicate level bubble. This was found to vibrate slightly, but constantly. The test was made many times, and on various piers, but always with the same result.

DISCUSSION.

MR. GEO. S. MORISON.—As Mr. Hudson's paper has, I believe, been brought out by one prepared by myself (read before the Western Society of Engineers, December 6, 1893, and published in the JOURNAL of December, 1893, Vol. XII, No. 12), it is perhaps right to call attention to one or two features in bridge building, or, rather, in bridging the Mississippi, which are briefly referred to in Mr. Hudson's paper, but are not really brought out either in his or in mine. He is entirely correct when he states that in the reconstruction there was very little work to do on the substructure. The piers, excepting for the deterioration which they had sustained, were as good as they had ever been. I think the condition of those piers, as compared with those in some other Mississippi River bridges, bears out all that he has said as to the excellence of the foundations. The piers of the Burlington Bridge were also much larger than those of most of the old single-track bridges. They are double the size of those of the Quincy Bridge, which was built at the same time. But our methods of putting in the substructure of bridges have undergone almost as great improvements as those that have been made in the manufacture of iron and of superstructures, and if, at the time of rebuilding the Burlington Bridge, I had had to build an entirely new bridge at the same site, I think the cost of the piers, using precisely the same spans, would not have been half the cost of the superstructure. In a bridge which I am now building, which is nearly completed, and which I expect to open in about six weeks across the same river, the foundations are all of that type of which the Burlington Bridge afforded the first instance. They are all pile foundations, the piles cut off ten feet below an extremely low water, the piers built on rafts with movable sides above, so that they can be floated into position. The piers are located on the piles substantially as at Burlington. Practically the only advance in the foundations of the bridge built in 1893 over that built in 1867 is in the method of doing the work, which has been very much simplified. The bridge referred to has approximately the same dimensions as the Burlington, but is rather longer and carries a much heavier load. The cost of the superstructure is very nearly twice that of the substructure. I make this statement merely to show how the reduction in the cost of work under water has progressed side by side with that in the cost of work above water. One of the greatest features of the Burlington Bridge, as originally built, and as described by Mr. Hudson, the feature that has done more than any other to facilitate the building of bridges across the Mississippi, is the fact that they succeeded in *doing work* under water without *working* under water. Their piles were driven from floating pile-drivers; their piles were cut off by machinery erected

above water, and the piers were built above water; so that any subaqueous work, excepting to the limited extent of examining foundations, was rendered unnecessary, and the Burlington Bridge is the first example of such practice. This feature characterizes the present cheap form of construction of piers in rivers like the Upper Mississippi, in which the current is so limited that it can very easily be controlled. At the Alton Bridge, the same method, somewhat modified, was employed; but that bridge has not yet been completed.

MR. THOMAS APPLETON.—I should like to ask Mr. Morison if, during the reconstruction of the bridge, soundings were taken to ascertain whether the form of cross-section of the river had changed, whether the depth had increased from what Mr. Hudson gives.

MR. MORISON.—Soundings were not taken at regular intervals during reconstruction, but they have been taken in the vicinity of the bridge for a great many years. Since Mr. Hudson retired from the Burlington Road, many things have occurred to affect the channel of the river. The west shore has been advanced something like 250 to 300 feet, partly by artificial constructions and partly by the natural results of such constructions. Furthermore, the line of railroad across the river-bottom east of the bridge was originally built with a good many pile openings, the greater part of which have since been closed. All this has had the effect of deepening the river, but the main features of the stream are substantially as they were. The sand bar still exists at the east end of the bridge and the deep water is still found on the other side.

MR. HENRY GOLDMARK.—Mr. Morison has told us that the substructure of this bridge could be built now for very much less than its original cost; but he has also told us that the substructure, as it was built, was a good, sound piece of work that has endured well for twenty-five years, and that, with some slight changes, is to do its work for many years more. Now the cost of the work is, of course, a very important item; but the permanence of the work is, I think, even a better measure of the skill of the engineer.

On the other hand, the superstructure of this bridge has been entirely renewed. The superstructures of many of these old bridges have been renewed because they were no longer able to do the work required of them. I understand very well that this work, owing to the increase in the weights of the engines and trains carried, is much greater than that to which they were originally subjected. But it is doubtful whether, even for the same loading, we could to-day pronounce the old superstructures safe, and, in general, I think we shall find that from the days of these early bridges even to the present time, the substructures have stood the test of time far better than the bridges they carry, in the West at least. And this has been the case, although we have had to

experiment with untried qualities of stone, and slowly learn the characteristics of our rivers, so different from those of eastern streams.

With all these drawbacks, honestly-built masonry piers of thirty years' standing are to-day as good as ever, and in many western roads are now supporting the third generation of truss spans. Now, it seems to me that the reasons for this difference are worth considering.

In the first place the pressure brought to bear upon the engineer in favor of a false economy in the first cost of substructure, has never been so great as in the case of the superstructure. When economy has been imperative, it has been usual to build the piers of timber, postponing the use of masonry until a later period. Iron trusses are too often pared down to the utmost limit of safety, but this practice has never been commonly applied to stonework or to timber framing.

In the second place, to a large extent, superstructures have in this country been built under the most severe competition, both as to design and as to workmanship. While nominally subject to specifications as to strength, they have been judged mainly by the dimensions of the truss members, regardless of the nature of the connections and of the character of the design as a whole.

The result of this has been to produce loose-jointed structures, built to conform to strain calculations at the lowest possible net cost, rather than careful designs.

It is an easy matter to check the sizes of main members, but it is difficult, in any specification, no matter how minute, to define the nature of details and connections so that all competitors shall be on an equal footing. Hence the tendency has been to use light details with heavy members, and thus many heavy and expensive bridges have been built which are really very weak in vital points.

In examining structures in use, I have found many which figured out very fairly as to the principal strains, and which as a whole contained enough weight of metal to make a good bridge, but which were still quite unsafe and therefore unfit for use.

On the other hand, I can recall not a few trusses in which the strains ran quite high throughout, but which were carefully designed in every detail and did not show a loose rivet nor any sign whatsoever that they were not capable of doing their work safely.

While the many able engineers in the employ of bridge companies have done a great deal in the last two decades toward the development of iron bridge work, there can be no doubt that they have been terribly handicapped by the circumstances under which they have had to work.

The good as well as the bad points of our existing bridges show that they were developed by the contracting company, and in the shop rather than by the civil engineer as such.

While they are as a rule built with every possible regard to facility and economy of construction and erection, it may be doubted whether sufficient attention has been given to the work they have to do afterwards. In other words, bridges in actual use are not as closely watched by competent experts as are other engineering works.

There has been too complete a division of labor. The office-work expended upon bridge superstructures should be supplemented by more of actual observation of the use of bridges during many years and under all sorts of circumstances. I think that if more of such observation had been brought to bear upon our bridge designs, we should have had more bridges that were practical; not designed by fine-spun theories, but better able to stand actual use and even abuse.

THE CONTRIBUTION BOX.

Members of the associated societies, and other persons, are invited to send to the Secretary, for this department of the JOURNAL, such matters of general interest as may come to their notice.

Sixth International Congress on Internal Navigation.

This Congress will be held at The Hague in July next, in accordance with a resolution adopted at the closing session of the Fifth Congress, held in Paris in 1892. The questions to be discussed will involve the construction of canals to be navigated at high velocities; the equipment of ports; methods of dealing with obstructions by ice; traction upon canals and rivers; tolls, etc. The proceedings will be printed in French, German and English. Excursions will be made, during and after the Congress, to Rotterdam, Amsterdam, Harlem, the Zuyder Zee, etc.

The Restoration of the Purdue Laboratory.

A circular, issued by the Purdue University, informs us that the damage occasioned by the fire of January 23d has been, in great measure, repaired, and that, by the opening of the fall term in September next, every machine, tool and piece of apparatus, formerly in the laboratory and necessary to carry on the instruction and practice provided for in the catalogue, will be in place and ready for use, and that many new features of great importance will be added.

The locomotive plant, for which this institution has become famous, will be removed from the general laboratory, and installed in a new building especially designed to receive it. The new plant will be larger and much more complete than the original, and will be capable of receiving and testing any locomotive whatever. A new traction dynamometer, especially designed for this part of the work, is now being built for the laboratory by William Sellers & Co., Incorporated, of Philadelphia.

In the steam engineering department, the two engines of a Vauclain compound locomotive, arranged to be mounted as a stationary engine and to be run with steam under the load of a friction brake, are being installed through the generosity of the Baldwin Locomotive Works of Philadelphia.

The 300,000 pound upright Riehle testing machine exhibited at the Columbian Exhibition has been purchased for the testing department. When it was exhibited it was the largest upright machine of the kind in the world. It will accommodate specimens up to ten feet in length, either in tension or compression.

Progress in Philadelphia.

The name of Philadelphia has from time immemorial been regarded by nonresidents as synonymous with lethargy; but a native who should now return to the

city after an absence of some years would be inclined to believe that the city had shaken off its slumbers and was rapidly coming to the fore. Its new City Hall, which for nearly a quarter of a century has been progressing with true Philadelphia deliberateness, and which is to cost something over twenty million dollars instead of the five millions originally estimated, has, for years, although still incomplete, been presentable as one of the finest buildings of the world. The two new railroad stations, those of the Pennsylvania and of the Philadelphia and Reading systems, the former of which is still incomplete, are by far the finest buildings of the kind in America, and will compare favorably with any stations in the world.

Even the streets, the paving of which has for years been a reproach to the city, are undergoing improvement, and at the present rate sheet asphalt will soon be almost as much the rule as the cobble was a few years ago. The Trades League, a body which has taken upon itself to look after the advancement of the city's interest, has published a list of items "wherein we are first," and among these are enumerated the Water Works, begun in 1799, Franklin's electrical discoveries, the matter of steam navigation, and the first experimental railroad track laid in the United States. The list, however, omits to mention the first pneumatic tube for postal purposes, laid down in the United States, and the largest, so far as diameter is concerned, in the world. This tube connects the main Post Office at Ninth and Chestnut Streets with the branch office at Fourth and Chestnut Streets, and is about half a mile long and six inches in diameter. It was described in an interesting paper recently read before the local Engineers' Club by Mr. A. Falkenau.

Every street-car system in the city has applied for and received permission to introduce the trolley system. Many of the lines have already applied it, and most of the others are rapidly preparing to put it in operation.

Not the least among the important operations now going on in this city is the erection of a large and handsome building for the Bourse.

The question now agitating the public mind is the proposed construction of a mis-called Boulevard, a straight avenue extending from the new City Hall northwestwardly to the nearest corner of the world-renowned Fairmount Park, and intersecting diagonally the intermediate checker-board blocks. The Boulevard was some time ago placed upon the city plan, but there is considerable doubt as to the advisability of constructing it, and a movement to remove it from the plan was recently set on foot. This movement has, however, been effectually blocked by a unanimous vote of the Survey Committee of Councils, retaining the new avenue upon the city plan.

Bearing Power of Foundations.

From the valuable note-book of Mr. E. L. Corthell, of the Western Society, we have been permitted to extract the following data respecting the bearing power of foundations:

CLAY.

From 2 to 8 or 9 tons per square foot, without allowance for friction.

SAND.

The different kinds vary greatly in bearing power. Sand mixed with loam will not bear more than 5 tons per square foot. 9.3 tons per square foot were placed on fine gravel and sand at Urk Viaduct; masonry piers on cylinders 4–8 inch diameter; friction neglected.

In India, on coarse sand in deep foundations, not over 9 tons are used.

In experiments 20 tons have been put on sand without measurable settlement.

FRICTION.

Side friction varies from 200 to 600 pounds per square foot.

All the above are in gross tons = 2,240 pounds.—B. Baker, April 17, 1888.

CLAY.

Black Friars Bridge, 5 tons per square foot. Settled badly.—Randall Hunt. *Engineering and Building Record*, June 23, 1888.

New London Bridge, 5 tons per square foot on piles, = 80 tons per pile. Settled badly.

Westminster Bridge, 2 tons per square foot; no settlement.

Old Westminster Bridge, 5½ tons per square foot; failed.

Newcastle-on-Tyne, 1½ tons per square foot; no settlement.

Fargo, Dakota, Four-Story Building, 2¼ tons per square foot; failed. Then 1½ tons per square foot; no settlement.

Cleveland, New Viaduct, 1 to 1.7 tons per square foot.

Washington Monument, 9 tons per square foot, inside edge. Clay and sand, 3 tons per square foot, outside edge.

SAND.

Coney Island Pier, 5 tons per square foot.

New York Steam Company's Chimney, 4 tons per square foot on fine sand; settled.

Brooklyn Bridge Anchorage, 4 tons per square foot.

Nantes Bridge, 6.8 tons per square foot; settled.

Berlin, considered safe, 2.3 tons per square foot.

Sometimes used to 4.1 tons per square foot.

Albany Capitol, 2 tons per square foot; settled.

Cairo Bridge, fatigue weight:

Channel piers, 3.34 tons per square foot.

River piers, 33.08 tons per square foot.

Friction on sides taken at 4,000 pounds per square foot; fine sand.

Sioux City, Pier III; sand, 2.64 tons per square foot.

SOFT SOIL.

India, 1 ton per square foot used.

The Box will be very glad to add to the completeness of this record from the experience of such of our readers as may have data of this kind at hand.

Cost of Earthwork.

From the same source of information we extract the following memorandum respecting the cost of steam-shovel excavation at the site of the Blair Bridge:

Haul, 2¼ miles; material excellent, loose, loamy clay; cars running to shovel by gravity; two trains of 14 cars each, 30 feet long; 5 cars at 50 cents and one engine at $6.50 per day, rented; the remaining plant owned; 5 yards in embankment, 6 yards loose on cars; carload work 6 months, 1885, April to September.

Total cost, including all employees, train crew and operator	$17,803.59
Number of carloads	32,141.00
Cost per carload	$0.05538
Cost per cubic yard	0.01107

Underground Electric Conduits in St. Louis.

St. Louis has followed the lead of several other large cities, and is about to undertake to solve the problem of putting its electric wires underground. A commission has been appointed, representing the four departments of the city government, the Mayor, the House of Delegates, the City Council and the Board of Public Works. This commission has thus far been occupied in collecting statistics and reports as to work of the same kind done in other cities. Its members propose to give a hearing to all parties immediately interested, beginning with those companies which have wires in the city streets. As the city has reached the limit of taxation and of bonded indebtedness, the commission has before it the difficult problem of constructing these conduits and enabling the city ultimately to own them. It will be several months before this commission has finished its labors.

New Specifications for Structural Steel for Modern Railroad Bridges.

Mr. George H. Thomson is perhaps best known to our readers and to the members of the American Society of Civil Engineers in his recent capacity of Engineer of Bridges of the New York Central and Hudson River Railroad. He has now, however, established himself as Consulting Engineer in the Wagner Palace Car offices at the Grand Central Station, New York City. Although Mr. Thomson quotes and evidently endorses Herbert Spencer's remark that "any test is liable to yield untrue results, either from incapacity or carelessness from those who use it," he has nevertheless established here a series of quite elaborate tests for bridge steel, trusting no doubt that they may be fortunate enough to fall into competent hands. The specifications, although brief, embody some radical departures from customary practice, chief among which is the requirement of careful watching of the process of manufacture from the ore heap to the finished piece, a process which Mr. Thomson requires shall be conducted at one establishment.

THE LIBRARY.

It is proposed to notice briefly in this department of the JOURNAL such engineering publications as may find their way to our shelves.

Publishers are requested, in sending works for review, to state the prices of same.

Heat and Steam. NOTES ON ——. By Prof. Chas. H. Benjamin, Case School of Applied Science, Cleveland, O. Pamphlet. 46 pages, 5 x 9 inches.

This volume, evidently intended as a handbook for the student, presents in convenient form for reference the principal definitions, rules, formulas and tables connected with the subject treated, together with a series of examples, for the working out and illustration of which blank pages are inserted at regular intervals. In Chapter II, which treats of Combustion and Fuel, various methods of smoke prevention are briefly referred to. Chapter II deals with chimneys, and gives rules for their draught-pressure, capacity and height. Chapter IV treats at some length of the principles of thermo-dynamics, and contains a table of the properties of saturated steam. The work concludes with Chapter V, which discusses steam and its use in the steam engine, the consumption of coal in engines, etc.

Brick for Street Pavements. An account of tests made of bricks and paving blocks, with a brief discussion of street pavements and the method of constructing them. New edition, with a paper on Country Roads. Prepared for the Engineers' Club of Cincinnati, April, 1894. By M. D. BURKE, C.E.

This pamphlet of 108 pages is based upon a series of tests of material to be used in paving the streets of Avondale, Ohio, where the author was employed as village engineer.

Circular letters were addressed to manufacturers and dealers, requesting them to send samples. In response to this letter, sixteen samples were received, including at least one specimen of granite, that from the Lithonia quarries, noticed in the JOURNAL for March.

The tests were so arranged as to determine the essential chemical ingredients, the ratio of absorption, the crushing and transverse strengths, and the resistance to abrasion and impact. The testing was done upon a Riehlé machine. Three cubes of each variety were set apart for the crushing test. These were sawed to a cube of 2 inches, cut from the interior of the brick, and the cubes were carefully dressed to the required size, with parallel and equal faces.

As might have been expected, the dressed cubes were found to have a higher ratio of absorption than the whole bricks, which of course retained their original glazed surface. For the resistance to abrasion and impact, the specimens were subjected to the rattling test, in which they were placed in a cylinder about 6 feet in length by 28 inches in diameter, containing pieces of iron weighing from one to six or eight pounds.

The manufacturers understand so well that a low rate of absorption is a desideration, and it is so easy for them to secure this quality, that but few street-paving blocks are in the market which absorb moisture as freely as most of the stone blocks.

Mr. Burke protests againsts the looseness and indefiniteness with which specifications for brick pavements are usually drawn, and submits a form of specification in which he endeavors to avoid these faults. He objects to the term vitrification as being a misnomer, signifying, as it does, to turn into glass by the action of heat, whereas all that is required in a paving brick is that the alkalies and alkaline earths shall form vitreous compounds with the iron and more readily fusible silica, so as to give the brick a dense, uniform texture, obliterating the granular appearance completely, but not fusing or melting the brick. Mr. Burke lays great stress upon the importance of the matrix, or material by which the paving blocks are cemented together. He mentions that in the work under his charge the substance used for this purpose was coal tar, and care was taken that it should not be poured unless it was smoking hot and perfectly liquid, that it should be poured carefully into the cracks without spreading over the surface, and that it should fill the cracks as completely as possible. Mr. Burke believes that in any city having a population less than 100,000 there are few, if any, streets upon which the traffic is so concentrated but that a well-constructed pavement may last for many years, and that the cost of maintenance of brick streets, when made of good material and upon a permanent foundation and subjected to moderate traffic, will be less than that of any other form of pavement, excepting granite blocks. The author severely scores the prevailing municipal methods in general, and municipal negligence of repairs in particular.

In the paper on Country Roads, which follows that upon brick pavements, no attempt is made to treat the subject either systematically or exhaustively. The author seeks merely to present certain features which practising civil engineers should endeavor to keep before the minds of those who expend moneys for road improvements, and to convey information applicable under existing regulations to the improvement of our common roads, calling attention to the methods by which existing evils may be greatly alleviated without adding to the burden of the taxpayer.

Association of Engineering Societies.

Organized 1881.

VOL. XIII. JUNE, 1894. No. 6.

DESIGN OF THE KING BRIDGE COMPANY'S NEW RIVETING SHOP.

BY GEORGE E. GIFFORD,
MEMBER OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read January 9, 1894.]

GENERAL DESIGN.

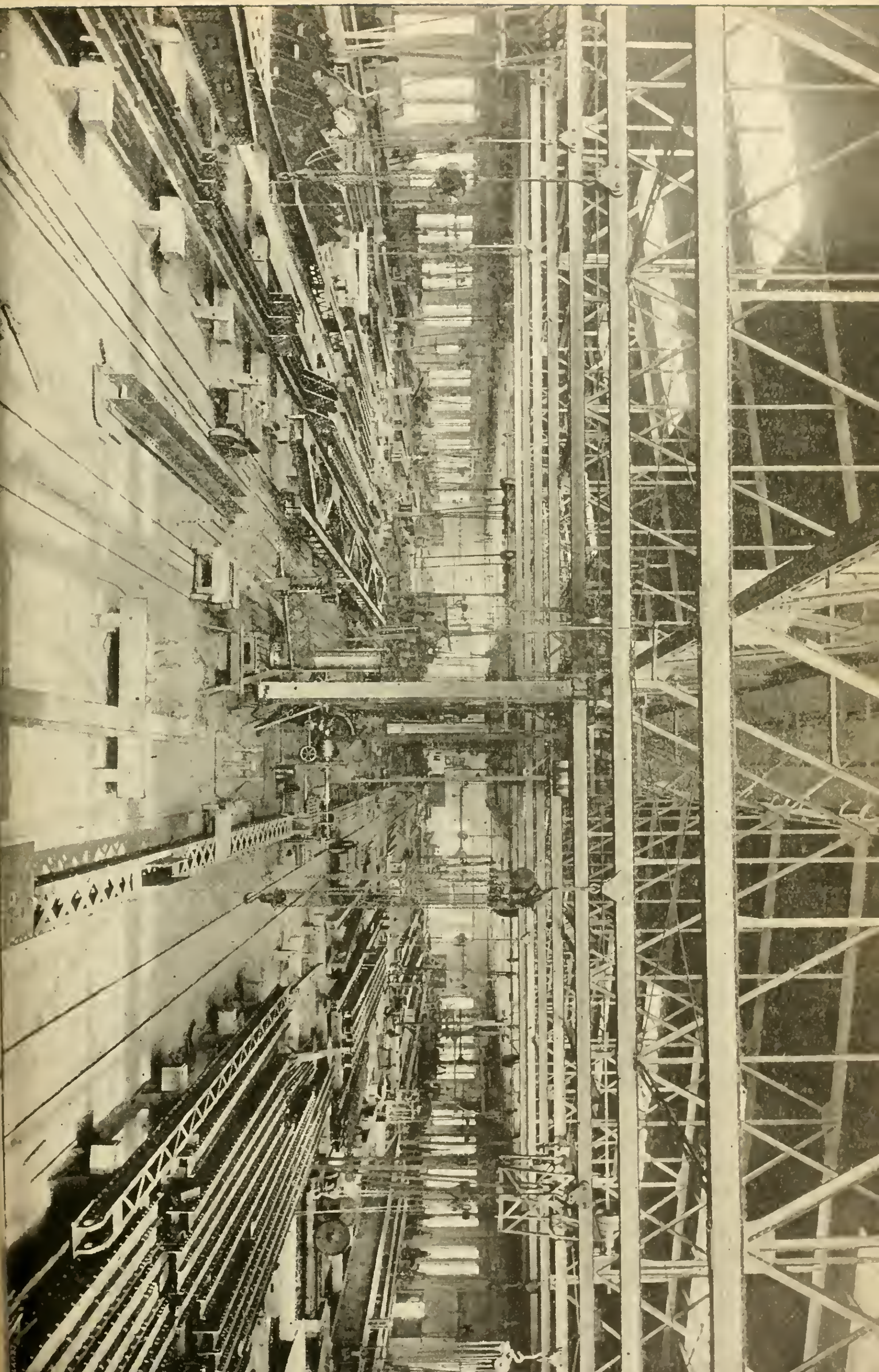
AFTER the two old riveting shops of the King Bridge Co. were destroyed by fire on May 19, 1893, it was decided to rebuild on a different plan, as the old shops had been found too narrow for the advantageous handling of work. One of these shops was 65 feet in width, the other 50 feet.

Before taking any steps towards preparing a definite plan, the writer, in company with the shop superintendent and master mechanic, spent a week in visiting shops in different parts of the country, noting designs of buildings, arrangements of machines and methods of handling work. It is needless to say that many valuable points were picked up, suggesting not only how to do some things, but also how not to do others. Before we had returned to Cleveland we had practically decided on the main dimensions of the building. This was to be not less than 200 feet in width, with a clear head-room of 22 feet. The length was to be as great as the Company felt that it could afford to build; the roof-trusses were to be spaced 16 feet centers, with as few supports in the interior of the building as possible; the roof was to be without valleys; and, for the sake of appearance as well as of economy, a high gable was to be

avoided. Above all, the building was to be as nearly fire-proof as it could be made, consistently with reasonable economy. With these features in view, the general design here illustrated was made.

The main dimensions are 200 feet by 320 feet center to center of walls; bottoms of trusses 22 feet above the bottom of the water-table, which coincides practically with the level of the shop floor. The trusses are spaced 16 feet centers, and are supported at their outer ends by pilasters in the brick side walls of the shop, and at the center of the building on longitudinal riveted girders, which in turn are carried by four columns 64 feet apart centers. There are, therefore, five bays, each 64 feet by 200 feet, in which there is no portion of the main structure to impede the free passage of material in any direction. In fact, the four columns, less than 2 feet square, and standing in the longitudinal center line of the building, are the only obstructions in the entire area of 64,000 square feet.

The ends of the building are closed by brick walls of the same height as the side walls. Above these are trusses of the same capacity as the intermediate trusses. These two end trusses are supported at their ends on the side walls and at the center on columns built into the end walls. The gable trusses are covered with corrugated iron, with glass windows. This construction admits of future extension at either end of the building at a minimum cost, while maintaining a completed and tight structure until such extension is made.



WALLS AND FOUNDATIONS.

The walls are of common brick laid in lime mortar. They are 12 inches thick, with pilasters 20 inches thick by 24 inches long, supporting the ends of the trusses. On the outside the bottom is finished with an 8-inch stone water-table, and the top is corbeled flush with the faces of the pilasters, which are set out 4 inches from the face of the wall. Below the bottom of the water-table the brickwork is laid with cement mortar and plastered on the outside. These foundation walls are 16 inches thick under the 12-inch wall and 20 inches under the pilasters. Beneath the 16-inch foundation walls is a 6-inch by 30-inch footing course of sandstone, and beneath the pilasters a footing stone 12 inches thick by 36 inches square. The general depth of the foundations below the bottom of the water-table is 2 feet 8 inches for walls and 3 feet 2 inches for pilasters. In some portions of the building, where the nature of the soil demanded it, the foundations are 1 foot and 2 feet deeper. The end walls are practically the same as the side walls, but, as they carry no roof load, the pilasters project beyond the face of the wall only on the outside, and are thus only 16 inches thick. The footing course is only 6 inches thick under the pilasters, instead of 12 inches, as at sides. The end walls are securely anchored to the end trusses by strap anchors at intervals of a few feet. The ends of the trusses are anchored to the side walls, by two $\frac{7}{8}$-inch bolts 30 inches long, built into the walls. In order to provide for possible discrepancies in the iron work, an opening 3 inches in diameter was left around these bolts for 15 inches down from the top of the wall, so that the bolts could be moved a little in any direction. After the roof was in place, these holes were poured full of cement.

The foundations for the center line of columns, which carry a maximum load of 272,000 pounds each, consist of three 12-inch solid stones, the bottom one $6\frac{1}{2}$ feet square, the top one $3\frac{1}{2}$ feet square. The bottom plates of the columns are 32 inches square, giving a pressure on the stone of about 265 pounds per square inch. Columns are set on a sheet of lead $\frac{1}{8}$ inch thick, and anchored to the foundations by four 1-inch bolts 30 inches long. These were set after the columns were in place, and were sulphured into stone.

METAL WORK.

The roof is supported by 42 riveted steel trusses of 100 feet span, which are in turn supported as already described. These trusses are so connected to the longitudinal girder as to form at the bottom chord a continuous runway from one side of the building to the other, except where they are connected to the columns. In the whole building there are thus fifteen of these runways, each 200 feet long. The trusses are all designed to carry a horizontal roof load of 30 pounds per square foot.

In addition to this, the first eight at the north end are figured for a concentrated load of 10,000 pounds at any point in the bottom chord, and the remainder for a concentrated load of 20,000 pounds at any point. The reason for making the first eight trusses (which cover one 64 foot bay) of less capacity than the remainder, was that this end of the building is used for handling the stock before assembling, and the single loads are thus much less than those handled from the other trusses.

The main trusses are built of plates, angles and channels.

The top chord is of T-shape, consisting of one 10-inch plate and two angles. Each web member is composed of two angles, placed back to back and thimbled every 3 or 4 feet.

The bottom chord consists of two 12-inch channels, weighing 20 pounds per foot for the 5-ton trusses, and 30 pounds per foot for the 10-ton trusses. These channels are spaced half an inch apart, back to back, and the gusset plates for the connection of the web members to the chords are riveted between them. The bottom flanges of the bottom chord channels form the runways previously mentioned, and on them run trolleys specially designed for the purpose of carrying chain hoists.

The riveted longitudinal girders, five in number, 64 feet long and 10 feet deep, are constructed mainly of angles. The top chord is stayed by a horizontal strut to every pair of main trusses.

To allow for expansion and contraction, these girders are provided with slotted holes at one end, as are also the main trusses.

The columns are of two 16-inch plates and four angles, latticed on two sides.

The purlins are 6-inch channels, spaced about 5 feet apart.

The ventilator framing is of angles, all connections being riveted or bolted.

Each pair of main trusses is stayed laterally in the plane of the bottom chord by a system of iron rods and struts. There being an odd number of trusses over each half of the building, the center truss is braced to each adjacent pair by struts only.

The top lateral bracing consists of rods in every fourth panel, with sway rods in the plane *B-a* at each end, and in the planes *K-l* at the center. The purlins act as struts, no special struts being provided.

The ventilator has lateral bracing in the same panels as the main roof.

In erection, all parts of the main trusses and girders were riveted. The ventilator trusses were riveted complete in the shop. The field connections of ventilator trusses to posts, side framing, purlins, supports for corrugated iron end covering and lateral connections were bolted. The main trusses, with the exception of the member *K-l* and the girders, were riveted up complete before raising. The riveting thus consists practically of shop work throughout.

The allowed working strains with the maximum loads are 15,000 pounds per square inch in tension and 14,000 pounds for compression, the latter being reduced by proper formulæ.

All material, except that of the lateral rods and bolts, is medium steel, which showed an average ultimate strength of about 63,000 pounds per square inch ; elastic limit 38,000 to 40,000 pounds; reduction of area 50 to 55 per cent.; elongation, 25 to 28 per cent. Nearly all the specimens tested closed down flat under the hammer without cracking.

The material was required to meet "manufacturers' standard specifications," but the record of the tests shows that most of the material was considerably better than those specifications require.

Although the Company had rigged up temporarily after the fire to do some work, it was not deemed expedient to attempt the manufacture of the metal work, except such as could be done in the blacksmith shop, and the little work to be done on the channel purlins. Arrangements were, therefore, made with outside parties, who did the shop work on the trusses, girders and columns.

The erection was comparatively simple. It presents no features of special interest.

ROOF.

The roof is sheathed with 1¾-inch by 6-inch pine stuff, matched and dressed. This is laid with joints up and down the roof and is fastened directly to channel purlins by 16 d. steel wire nails clinched under the top flange. This method has proved perfectly satisfactory. The planks were drawn together and down to the purlins as well as if they had been nailed to wooden purlins.

The 45-degree slopes at the sides of the main roof and the quarter-pitch roof over the ventilator are covered with a layer of slater's felt and slated with sea-green slate.

The main decks, 81 feet by 325 feet, with a pitch of 1½ inches per foot, are covered with a three-ply felt and gravel roof. This is fastened by nails spaced 10 inches apart up and down the roof, in rows 30 inches apart, with circular tins between the felt and the head. The layers of felt are cemented together with coal tar, and over the whole is a heavy coating of coal tar, in which is bedded a layer of gravel about half an inch thick.

LIGHTING.

The shop is lighted by windows in the walls, two to each panel, except where there are doors. These windows have thirty-two 9-inch by 16-inch lights each. There are 93 of this size in the sides and ends, and several smaller ones where the location of doorways, etc., prevents the use of full-size windows. Altogether there are some 3,100 square feet of glass in the side windows.

The sash in these windows are hung to each other with a small wire rope running over a pulley in the frame, so that when the lower sash is raised the upper one falls through an equal distance.

In each gable are 40 sash of thirty 9-inch by 12-inch lights each, giving an area of 900 square feet of glass. These sash are bolted directly to the steel framework, and are not movable.

The sides of the ventilator are practically all glass. Each panel has four sash, the two middle ones hung on a horizontal central axis, and so arranged as to swing bottom out and capable of being fastened at various positions from nearly horizontal to tight shut, thus affording ventilation as well as light. There are 1,440 square feet of glass on each side of the ventilator. All portions of the ventilator sides not covered by glass are sealed with galvanized iron, and around all sash and places liable to leak are flashings of galvanized iron. The result is a good, water-tight job.

In the main decks are 20 skylights, 10 on each side in alternate panels. These lights are 10 feet by 30 feet each, giving a total of 6,000 square feet of skylight area, or nearly one-tenth of the whole roof area. They are glazed with $\frac{1}{4}$-inch ribbed glass, set in putty and supported by galvanized iron framework. On account of this portion of the roof being so nearly flat, it was necessary to adopt for the skylights the form known as "shed lights," in order to get the requisite pitch. These are simply small roofs of $\frac{1}{4}$ pitch, with the ridge running at right angles to the main ridge. The gables are enclosed with galvanized sheet iron, and the sides and ends are carefully flashed with the same material.

The lighting may be said to be practically perfect. The workmen can see as well and as long on a dark afternoon, as if they were out of doors.

At night the shop is lighted by twenty-five 1,200 c.p. arc lights.

DRAINAGE.

The amount of water running off a roof of this size during a heavy storm is considerable, and it was early seen that some special provision must be made for it, as no portion of the Company's plant, except the office, was connected with a sewer. It was determined to construct a sewer connecting with the Hoyt Avenue sewer, both because this sewer gave a better fall than the one in Ruskin Street, and because it was nearer to the building. It was, however, necessary to purchase right of way across a piece of property lying between the Company's plant and Hoyt Avenue.

It was also determined to build a workmen's water-closet and washroom to connect with this sewer, using the roof water for flushing. This closet is built over an open vault 4 feet by 24 feet, from 5 to 6 feet deep,

with brick walls plastered with cement; the storm water passing through it, and arrangements being made for flushing in dry seasons.

The drainage pipes along the sides of the building are 6-inch crocks, receiving the roof water from galvanized iron down-spouts. The vault is located east of the new building, between it and the old forge shop, and about one-third the distance from the north end of the new shop. It was thus necessary to bring the storm water from the western half of the new building across the shop, for which purpose an 8-inch pipe is used. A 9-inch pipe leads to the vault from the point where the 8-inch pipe joins the 6-inch pipe on the east side; and from the vault to the street sewer is a 12-inch pipe, with a manhole near the vault. Altogether there are about 1,000 feet of sewer.

PAINTING.

The corrugated and galvanized iron and wood work outside are painted with two coats of red iron ore paint and boiled linseed oil.

The iron work and wood work inside are painted two coats of white lead and oil, with a faint tinge of blue. The brick walls are white-washed. This white paint inside very effectually aids the lighting of the shop.

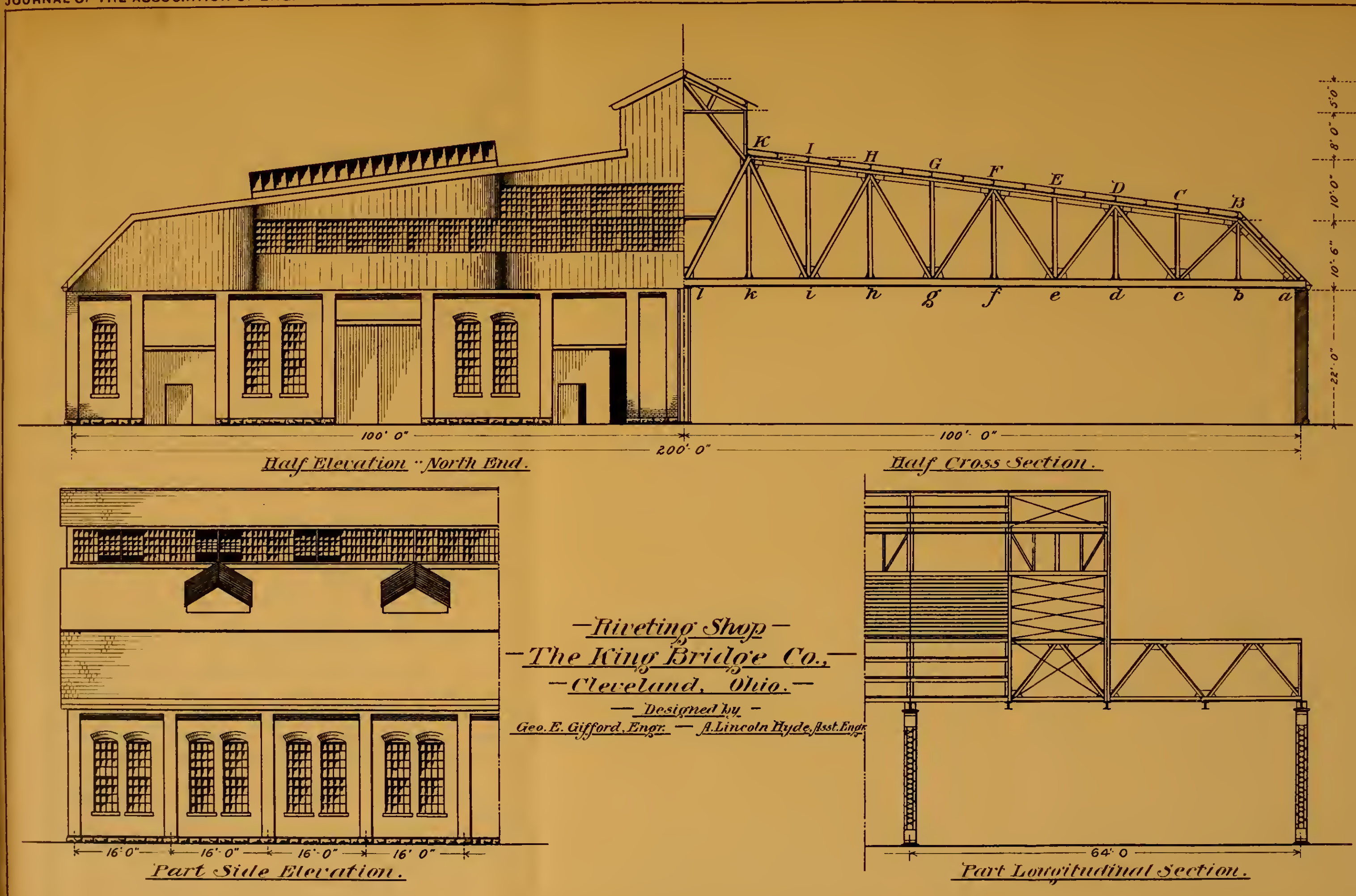
METHOD OF HANDLING WORK AND ARRANGEMENT OF MACHINE TOOLS.

The underlying principle in the handling of work in this shop is its passage from the north end of the shop, where the material enters as plates, angles, channels, etc., from the rolling mills, to the south end, where it leaves as completed chords, girders, posts or whatever it may be, with as little handling and moving, and especially with as little backward movement, as possible. There are in fact two distinct shops, one in each half of the building, each so completely fitted with tools that a bridge can be entirely built on one side without coming into the other, while at the same time the system of overhead runways permits the easy transfer of work from one side to the other, if desirable. Work is moved longitudinally by means of buggies running on narrow-gage tracks on the ground. There are also tracks running transversely, so that material may be carried in either direction on buggies. At the intersections of the tracks are cast-iron turntables. Generally, however, the work is moved transversely by the overhead runways.

Light jib cranes, each with a horizontal boom on which travels a trolley carrying a chain hoist, are used for the support and handling of material at the shears, punches, etc.

There are also short supplementary longitudinal runways for moving material before the machines.

The arrangement of tools and machines is such as to conform as


K I H G F E D C B
l k i h g f e d c b a
5' 0"
8' 0"
10' 0"
10' 6"
22' 0"
100' 0"
100' 0"
200' 0"
Half Elevation - North End.
Half Cross Section.
–Riveting Shop–
–The King Bridge Co.,–
–Cleveland, Ohio.–
–Designed by–
Geo. E. Gifford, Engr. — A. Lincoln Hyde, Asst. Engr.
16' 0"
16' 0"
16' 0"
16' 0"
Part Side Elevation.
64' 0
Part Longitudinal Section.

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nearly as possible to the above scheme. The material enters at the north end, either by buggies from the storage yard outside, or on cars which can be run into the building for a distance of about 70 feet. It is here laid out by templet, plates are straightened and sheared, and angles sheared and the material then goes to the punches, which are near at hand. From the punches it is carried a short distance to wooden horses, where it is assembled or "fitted up." If required to be reamed it is carried to the radial drills near the walls, and then across to the riveters at the center of the shop. From here it passes on to the rotary planers for facing the ends, and then to the drills to be bored. It is then laid on horses again to be chipped, painted and generally finished, and then taken outside to be loaded or stored.

Girders or floor beams which require no reaming, facing or drilling, pass directly from the punches to the south end, where they are assembled and riveted under the riveting runways at the south corners, and then go outside at once.

There can, of course, be no invariable method of moving the work along, for much depends on the kind and the quantity of work in the shop at any given time, but it is believed that the system outlined, which was planned by Mr. Arthur Clarke, superintendent of the shop, is the most effective and economical one for this class of work.

POWER.

Perhaps the question longest under discussion in the design of this shop was the method of driving the machines. Very serious thought was given to the idea of equipping them with electric motors to be driven by a generator connected with the 14-inch by 42-inch Hamilton-Corliss engine, which was already in place and which had not been touched by the fire; but for several reasons the scheme was abandoned. First, there was much old material, such as pulleys and hangers, not ruined by the fire, that could be fixed up and used again; second, the plan would have required an entire remodeling of the engine room, as the engine had not only to drive the new generator, but to continue to drive, by means of shafting and belting, the machines already in use in the forge and machine shops, and there was not room enough to set up the generator without providing a new place for it; third, the estimates submitted by several electric companies were so far in excess of the estimated cost of shafting, pulleys, belting, etc., that the company, already under a heavy expense in a dull season, shrank from incurring the greater outlay.

The machines are, therefore, driven by means of belting and shafting, as they were in the old shop, and by the same engine working in the same location.

After it was decided to use this method of providing power, the question came up whether to raise the shafting in the new shop so that it should hang just below the trusses, or to keep it at the level of the old line shaft from the engine room. The old shaft was 17 feet high, or 4 feet lower than it ought to be. The question then was, should the shafting be carried about the building on a system of trussed supports, 5 feet below the bottom chords, or should a large pair of gears be put in at the wall where the line-shaft enters the building, raising the line to the desired height. The latter method offered greater head room and increased stiffness in the supports for the shafting, as well as a saving in cost. The main objections to it were the loss of power in the gear and the necessity for introducing considerable bracing and support; for, on account of jar and vibration, it was not thought safe to rest a box on the wall. The gears were, however, adopted, and were supported at the wall by a braced frame of A-shape, resting on the ground and braced to the trusses at the top.

One of the gears is of cast iron, while the other is a "filled" gear having teeth made of maple. They run very smoothly and noiselessly, but have required adjustment once or twice on account of settlement of the "A" frame or of the supports of the main shaft outside the building, or both.

The shafting throughout the shop is supported by cast-iron hangers depending from steel girders made of 10-inch channels, latticed. These girders are supported on top of the bottom chords of the trusses and securely bolted to them. This system is very rigid, and it certainly ought to reduce "getting out of line" to a minimum.

As the machines have been arranged throughout the shop with reference to their convenience to the work they have to do, and not with regard to centralization on a line shaft, the amount of shafting is considerable, and several pairs of mitre gears have been introduced for changing the direction of the shafting. It was feared that the resistance of this large amount of gearing and shafting might test the engine severely; but, owing to the good alinement and solid bearings, the engine does its work with apparent ease.

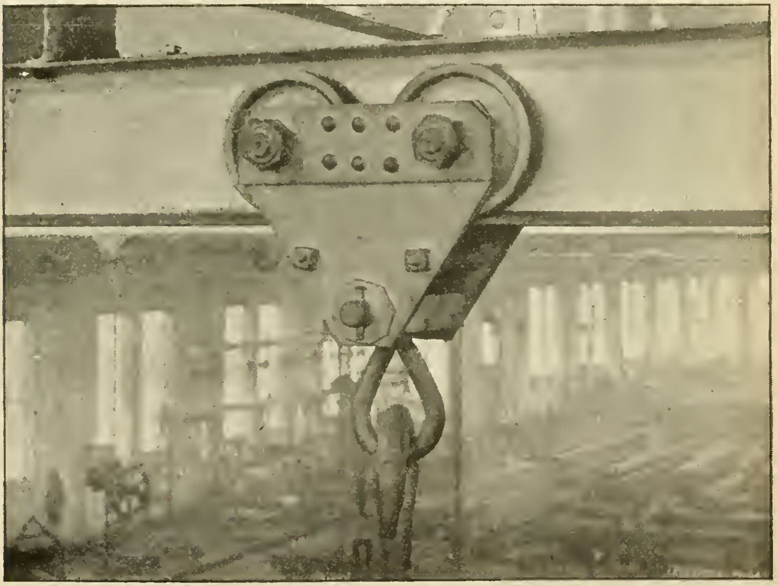
There are in the shop two small upright engines which can be connected to certain portions of the main shaft, other portions being thrown out of gear by means of clutches. These are so arranged as to run a small number of tools which may be crowded with work at night, without running the big engine.

SPECIAL APPLIANCES.

It may be of interest to note a few of the appliances that have been designed especially for use in this shop.

The trolleys for use on the bottom flanges of chord channels have been already mentioned. Each trolley has four cast-iron wheels 10-inch diameter, 2½-inch face, turning on steel pins 2-inch diameter, by means of fifteen half-inch cold-rolled steel rollers. On account of the shape of the flanges, the wheels cannot stand vertical, but are inclined towards each other at the bottom. The two side plates are 16 inches deep by 18 inches long and ½-inch thick, trimmed at the bottom so as to present a neat appearance, and reinforced by a 6-inch by ½-inch bar at the top, where they take the pins. The plates conform to the inclination of the wheels until they pass below the bottom of the chord. when a slight bend brings them to a vertical position.

The chain hoist is hooked into a 1¼-inch loop riveted into a forged bar shouldered down at each end to 1¾-inch diameter and supported in holes near the bottom of the two side plates. These trolleys will carry 8 tons.



TROLLEY FOR BOTTOM CHORDS OF TRUSSES.

For handling the portable compressed-air riveters, and for moving pieces of work before the fixed steam riveter, there have been devised systems of overhead runways, supported by the trusses and extending longitudinally. Near the center of the shop are two of these runways, each 80 feet long, and in each south corner one 128 feet long. On the runways carriages are operated by means of a hand-chain passing over a wheel keyed to one of the shafts.

The track is a 67-pound steel rail carried some two feet below the bottom chords of the trusses by means of bent angle hangers riveted at the top into the channel girders supported on the main trusses. They are strongly braced in all directions. These runways are arranged in pairs, the rails being about 10 feet apart, and the carriage traveling between them. Underneath each truss the rail is cut so as to leave a space of 7 inches for the passage of the trolleys running on the trusses. The carriage has six wheels, three at each end, so that two are always bearing on the rail, and the wheels are thus prevented from getting fast in the gaps in the rail.

Riveted between the end plates of the carriage is a 12-inch I-beam on which runs a trolley for moving the riveter or work transversely.

RIVETING RUNWAY AND CARRIAGE.

The trolley has a travel of about seven feet. All journals in the carriages and trolleys have roller bearings. All parts are designed to carry five tons.

The question of heating so large a space as that included in this shop was quite a serious one. The idea of any general heating system, such as by steam radiators or hot air, was early abandoned on account of the cost. Of course it is not necessary that the temperature be kept so high as in shops where the employés are engaged in less active labor, and the numerous rivet-heating furnaces help materially in heating the air. But there are many parts of the shop where men are engaged in occupations requiring but little bodily exercise, such as laying out work; and for these places it was desirable that some means of local heating should be introduced. Mr. H. W. King, Vice-President of the Company, suggested the use of stoves with crude oil such as is used in all heating furnaces throughout the works. This scheme has been elaborated, with the result that the temperature of the shop is always comfortable. The stoves are simply rectangular boxes of fire brick about 2 feet by 4 feet, and 2 feet deep, open on top, and placed partly in the ground and partly out. On top are set cast-iron cylinders brought in at the top into spherical shape, with a hole about 6 inches in diameter for draught. These cast-iron stoves act simply as radiators. The oil is introduced at one end of the brick box, and is sprayed by an air blast just as is done in all the heating furnaces. These stoves are excellent heaters and will keep the air comfortable for many feet around them, while the cost of fuel is very slight and that of operation is practically nothing.

OTHER IMPROVEMENTS.

It may be of interest to mention certain other improvements made by the Company as a direct result of the recent fire, although these may not be strictly pertinent to the subject of this paper.

Between the new riveting shop and the old engine room is a steel frame building 32 by 33 feet 9 inches, covered with corrugated iron. Its trusses carry the main shaft across the space between the two buildings. It is used for the manufacture of rivets and contains the blower which supplies blast to the heating furnaces and stoves in the new shop.

The *pattern and templet shop* is a wooden frame building 50 feet by 130 feet, covered inside and outside with corrugated iron: equipped independently with engine and wood-working machinery, with large floor space for laying out templets full size.

The *packing building* is a wooden frame building 24 feet by 70 feet, covered with corrugated iron, for storing and packing bolts and other small matters, for storing erecting tools, making boxes, etc.

The *shippers' and inspectors' building* is a wooden building 14 feet by 17 feet, located beside the shipping scales and containing a scale beam. It furnishes an office for the shipping foreman, the company's inspector and the outside inspectors.

The *paint shop*, 16 feet by 30 feet, is built entirely of iron and located in a corner remote from other buildings. It is used for storing and mixing paints, oils, etc.

In the near future there will doubtless be erected a loading and shipping shed 100 feet by 160 feet, of steel and corrugated iron. This will be located near the south end of the new shop, so that work can be run straight into it from one corner of the new shop. It will cover the shipping scales and the shipper's building, and will afford a large area for storing and painting material before shipment.

In accrediting the design and execution of the work described in this paper, the writer would acknowledge the assistance he has received from Mr. A. Lincoln Hyde, who had charge of the preparation of the working plans for the whole work, and who designed many of the details and appliances described. Mr. W. P. Brown inspected the iron work at the shops, prepared many of the working plans and made the surveys for the foundations of the building.

Acknowledgment is also due to Mr. H. W. King, Vice-President of the Company, and to Messrs. Clarke and Parker, Superintendent and Master Mechanic respectively, for many valuable suggestions and for the careful execution of the work in their departments.

NEW FORMULAS FOR CALCULATING THE FLOW OF WATER IN PIPES AND CHANNELS.

By William E. Foss, Member of the Boston Society of Civil Engineers.

[Read March 21, 1894.]

The formulas presented herewith have been derived from existing experimental data. It is believed that their great simplicity will render them of value to the profession, while their results agree with those of experiment fully as well as do those obtained from the more complicated formulas now in use.

A new formula for calculating the flow of water in pipes by M. Flamant, Chief Engineer of the Ponts et Chaussées, was published in the *Annales des Ponts et Chaussées* of September, 1892. My attention was called to the article by Mr. Desmond FitzGerald soon after its publication. As the formulas which are about to be presented were suggested by a study of this article, a brief description of it will first be given.

M. Flamant states that all of the formulas for calculating the flow of water in circular pipes may be reduced to the general form:

$$\frac{D\,I}{4} = b'\,V^2;$$

in which

D = diameter of pipe.
I = slope per unit of length.
V = mean velocity of the water.
b' = a coefficient, the form and value of which are to be determined.

In seeking to obtain the form and value for the coefficient b', M. Flamant found that if a and b represent numerical coefficients which have different values according to the various authors, then

According to Prony $\quad b' = a + \frac{b}{V}.$

" " Darcy $\quad b' = a + \frac{b}{D}.$

" " Weisbach $\quad b' = a + \frac{b}{V^{\frac{1}{2}}}.$

" " M. Albert Frank $\quad b' = a + \frac{b}{D^{\frac{1}{2}}}.$

" " Hagen $\quad b' = a + \frac{b}{D\,V}.$

As theory offered no indication by which to choose between these different forms, M. Flamant decided that recourse must be had to investigation, and that the first step should be to collect the records of all reliable published experiments, and to bring the results together under comparable forms.

Ninety-two series of experiments by twenty-three authors, and comprising 552 observations, were collected, and the coefficient b' was calculated for each. In studying these results for the purpose of determining the proper form for the coefficient b', M. Flamant concluded that a formula obtained by adopting any of the forms for b' just mentioned, must fail to agree satisfactorily with the experiments, and could not take into account the variations due to changes in roughness, diameter and velocity, without leading to inadmissible complications. To avoid this he sought to express these variations by a monomial formula of the form $b' = a\, D^m\, V^n$. Prof. Unwin had suggested the formula: $I = b \frac{V^n}{D^{3-n}}$, and M. Flamant reduced this to the general form, and obtained:

$$b' = \frac{a}{(D\, V)^{2-n}}.$$

Prof. Unwin had proposed for the exponent n values comprised between 1.79 and 1.95, and Prof. Osborne Reynolds had concluded from experiments made by him that the loss of head I varied as the 1.722 power of the velocity for lead pipes, and by powers of which the exponent approached 2 as the roughness increased. From these facts M. Flamant concluded that $n = 1.75$ could be adopted as a mean value. This would give $b' = \frac{a}{(D\, V)^{\frac{1}{4}}}$. The justification of this proposed form is then presented. In order to facilitate the discussion M. Flamant sought first to demonstrate that if the diameter remains constant, the variation of b' with the velocity can be represented by the form $b' = \frac{b}{V^{\frac{1}{4}}}$. Then, for pipes of the same nature, he sought to establish the form $b = \frac{a}{D^{\frac{1}{4}}}$, the coefficient a having values varying with the nature and condition of the pipe. Then for circular pipes, calling Q the discharge, substituting for V, $\frac{4}{\pi}\frac{Q}{D^2}$, and reducing, the form $\frac{1}{Q^{\frac{7}{4}}} = \frac{\gamma}{I}$ was obtained, in which γ is a function of the diameter and $= 4\, a\, \frac{1}{D^{\frac{19}{4}}} \left(\frac{4}{\pi}\right)^{\frac{7}{4}}$.

M. Flamant states that for practical use a table of values of γ can be calculated for all of the usual diameters, and also a table giving in function of the discharge Q the value of $\frac{1}{Q^{\frac{7}{4}}}$, by means of which the

solution of all of the problems for the flow of water in pipes is rendered simple.

From a careful study of M. Flamant's article and of the experiments and diagrams presented, it was concluded that by means of his formula the solution of problems relating to the flow of water in pipes of small diameters, of lead, tin and glass, etc., having very smooth surfaces, had been very much simplified.

For pipes of larger diameters, say of 4 inches and over, and having rougher surfaces, such as that of cast iron, it seemed possible to construct a monomial formula, as simple in form as that of M. Flamant and agreeing better with the results of experiment. The reasons for this belief were the following. Referring to the formula suggested by Prof. Unwin and previously mentioned, $I = b\,\frac{V^n}{D^{3-n}}$, from which M. Flamant derived his formula, it will be noticed that Prof. Unwin had suggested values for n varying from 1.79 to 1.95, and that Prof. Reynolds found that n should be 1.722 for lead pipes and that its value approached 2 as the roughness increased.

M. Flamant adopted 1.75 for a mean value. This was very nearly the same as Prof. Reynolds had found for lead pipes, and less than the lowest value given by Prof. Unwin. It seemed to me, therefore, that 1.75 for n was too low for a mean value, and this view was confirmed by a comparison of the results obtained from M. Flamant's formula with the conclusions of Hamilton Smith, Jr., given in his "Hydraulics," and by a study of the investigations of Prof. Unwin and Prof. Reynolds.

DERIVATION OF A NEW FORMULA.

Variation with velocity.—Experiments made by various authors lead to the conclusion that when water and a solid surface are in relative motion the resistance varies with V^n, the exponent n varying with the degree of roughness of the surface, being lowest for the smoothest surfaces and increasing as the roughness increases.

The following experimenters have found values for n varying from 1.7 for surfaces of lead and tinfoil to 2.16 for surfaces covered with sand. The velocities covered by the experiments range from 0.5 foot per second to 23 feet per second.

* Col. Beaufoy—Experiments on resistance of smooth painted plank drawn through water.

* W. Froude—Experiments on the resistance of planks covered with various materials and towed in water.

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* Encyclopædia Britannica, subject "Hydromechanics."

* Prof. W. C. Unwin—Experiments on disks revolved in water.

† Prof. Osborne Reynolds—Experiments on the flow of water in pipes.

‡ J. G. Mair—Experiments on the flow of water in a brass pipe.

It has, moreover, been shown by Prof. Reynolds that in the experiments made by M. Darcy on the flow of water in pipes, the resistance varied with V^n, n having values of from 1.79 for pipes having the smoothest surfaces to 2.1 for the pipes having the roughest surfaces.

M. Flamant has shown that in the experiments of Du Buat, Bossut, Darcy and Hamilton Smith, Jr., on lead, tin and glass pipes, the resistances varied closely with $V^{1.75}$.

Variation with Diameter.—The formula $I = b \frac{V^n}{D^{3-n}}$ suggested by Prof. Unwin is given in the *Engineer* of January 1, 1886. It was reduced, by neglecting the temperature coefficients, from a more complicated formula given by Prof. Reynolds.†

By this formula, for pipes of the same nature but of different diameters, the resistances vary with $\frac{1}{D^{3-n}}$.

M. Flamant has shown that, in the experiments of Du Buat, Bossut, Darcy and Hamilton Smith, Jr., on lead, tin and glass pipes of different diameters, the resistances varied closely with $\frac{1}{D^{1.25}}$.

From these facts I was led to believe that the form $I = b \frac{V^n}{D^m}$ could be adopted for a general formula for the flow of water in pipes.

The advantages of this form are its great simplicity and its adaptability to surfaces of any degree of roughness provided the coefficient b and the exponents n and m vary with the roughness. To justify this form we first seek the variation of I with V^n, the diameter remaining constant, and then the variation of I with $\frac{1}{D^m}$, the velocity remaining constant. The values for the exponents n and m and the coefficient b have been sought for new cast-iron pipes and for riveted sheet-iron pipes, these being the forms of pipe most frequently used in practice. It was believed that a formula based on these degrees of roughness could be used for surfaces of other degrees of roughness and give results quite as reliable as those of the more complicated formulas now in use.

The experiments that have been used in obtaining the values for the exponents n and m and the coefficient b are the following:

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* Minutes of Proc. of the Inst. of C. E., Vol. 80, p. 221, 1884.

† Proceedings and Transaction, Royal Soc. of London, 1883.

‡ Minutes of Proc. of the Inst. of C. E., Vol. 84, p. 424, 1886.

NEW CAST-IRON PIPES.

No.	Diam. in feet.	Length in feet.	Loss of Head per foot. I.	Mean Vel. Ft. per sec. V.	Name of Author and Description of Pipes.
			Series No. 1.		Darcy.
1	.2687	366.1	.0002	.289	
2	"	"	.00083	.561	
3	"	"	.00232	1.175	
4	"	"	.00531	1.841	
5	"	"	.0102	2.595	
6	"	"	.02255	3.888	
7	"	"	.03208	4.652	
8	"	"	.04041	5.154	
9	"	"	.09547	8.048	
10	"	"	.09904	8.160	
11	"	"	.11978	8.924	
12	"	"	.16807	10.623	
13	"	"	.17072	10.712	
			Series No. 2.		Darcy.
14	.4495	365.7	.00024	.489	
15	"	"	.00087	.978	
16	"	"	.00209	1.601	
17	"	"	.00475	2.503	
18	"	"	.01260	4.196	
19	"	"	.02225	5.623	
20	"	"	.03318	6.883	
21	"	"	.03905	7.484	
22	"	"	.09852	11.942	
23	"	"	.16756	15.397	
			Series No. 3.		Darcy.
24	.6168	365.4	.00027	.673	
25	"	"	.00175	1.631	
26	"	"	.00368	2.487	
27	"	"	.00805	3.701	
28	"	"	.01340	4.882	
29	"	"	.0225	6.342	
30	"	"	.0381	8.222	
31	"	"	.10980	14.183	
32	"	"	.14591	16.168	
			Series No. 4.		Darcy.
33	1.6404	365.3	.00045	1.380	
34	"	"	.00045	1.472	
35	"	"	.0006	1.559	
36	"	"	.0012	2.602	
37	"	"	.00125	2.609	
38	"	"	.0021	3.416	
39	"	"	.0023	3.653	
40	"	"	.0026	3.674	
41	"	"	.0025	3.700	

New Cast-Iron Pipes.—Continued.

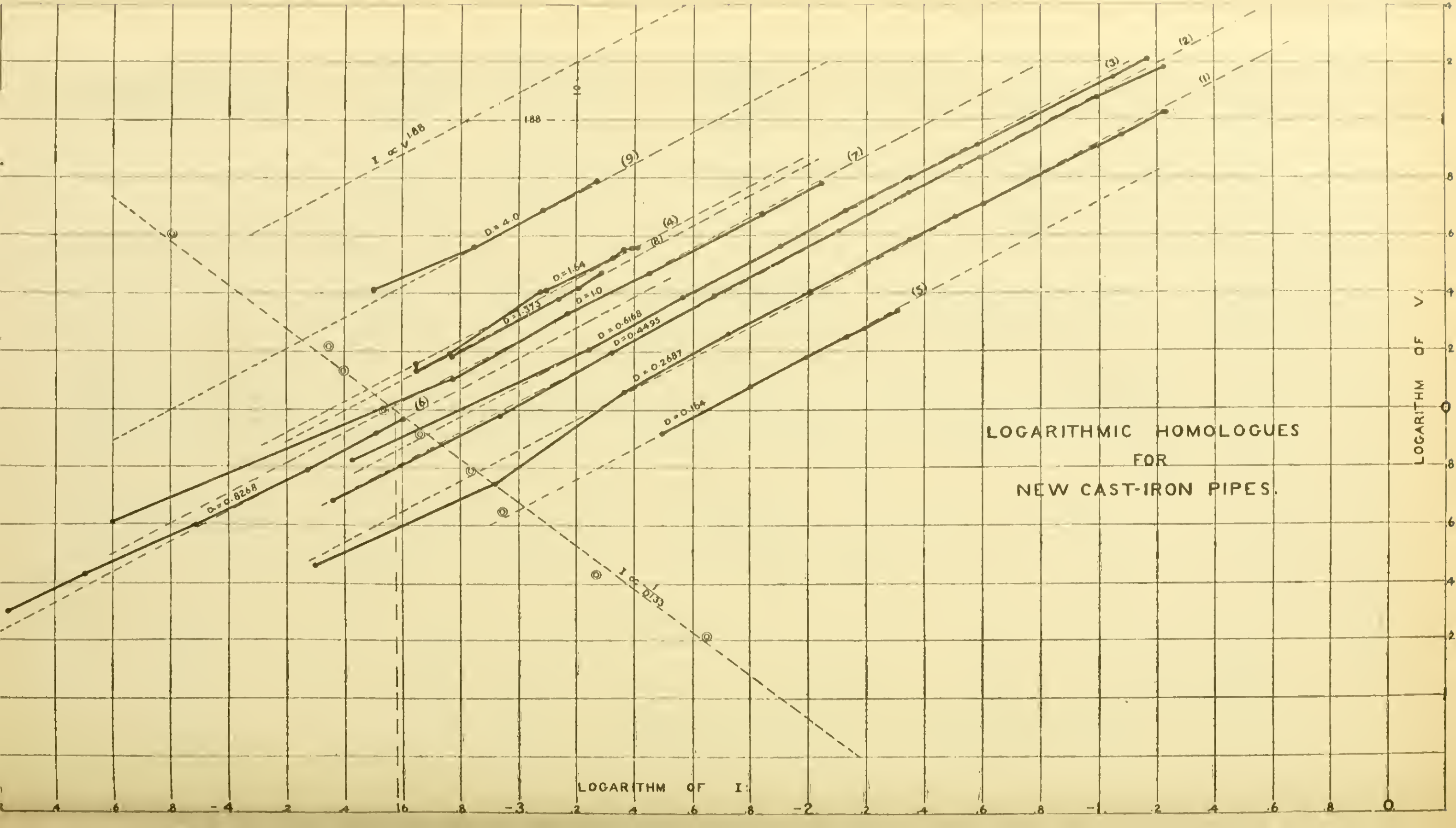
No.	Diam. in feet.	Length in feet.	Loss of Head per foot. *I.*	Mean Vel. Ft. per sec. *V.*	Name of Author and Description of Pipes.
			Series No. 5.		Ehmann.
42	.164	2139.1	.00315	.840	
43	"	"	.00638	1.220	
44	"	"	.00974	1.522	Coated with Asphaltum.
45	"	"	.01371	1.801	
46	"	"	.01566	1.932	
47	"	"	.02025	2.201	
			Series No. 6.		Ehmann.
48	.8268	1131.9	.0000174	.200	
49	"	"	.0000319	.269	
50	"	"	.0000783	.400	
51	"	"	.000188	.620	
52	"	"	.000328	.830	
53	"	"	.000406	.942	
			Series No. 7.		Iben.
54	1.00	580.7	.00004	.400	
55	"	"	.0006	1.300	
56	"	"	.00149	2.201	
57	"	"	.00284	3.002	
58	"	"	.007	4.803	
59	"	"	.01122	6.102	
			Series No. 8.		Dr. Lampe.
60	1.373	46352.	.001950	3.090	
61	"	"	.001630	2.709	Coated with Patent Varnish.
62	"	"	.001376	2.479	
63	"	"	.0005936	1.577	
			Series No. 9.		Stearns.
64	4.00	1747.2	.0003180	2.6155	
65	"	"	.0007115	3.738	Coated with Coal Tar and Asphaltum.
66	"	"	.001221	4.965	
67	"	"	.001849	6.195	

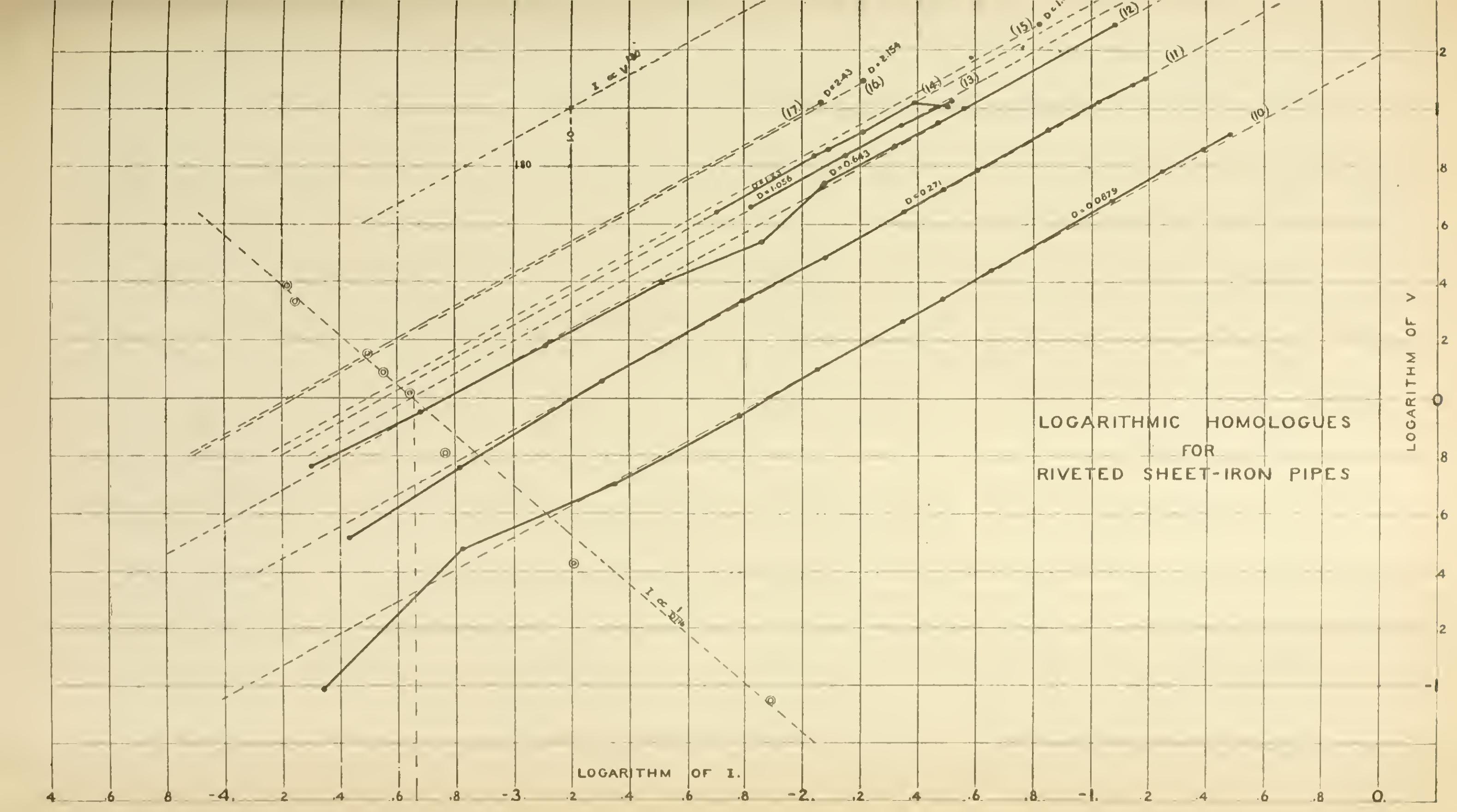
COATED RIVETED SHEET-IRON PIPES.

			Series No. 10.		Darcy.
68	.0879	371.8	.00022	.098	
69	"	"	.00067	.302	
70	"	"	.00224	.509	
71	"	"	.00609	.889	
72	"	"	.01133	1.260	
73	"	"	.02221	1.860	Covered with Bitumen. New Pipe.
74	"	"	.03035	2.224	
75	"	"	.04540	2.798	
76	"	"	.11846	4.813	
77	"	"	.17985	6 099	
78	"	"	.24419	7.228	
79	"	"	.30714	8.225	

COATED RIVETED SHEET-IRON PIPES.—Continued.

No.	Diam. in feet.	Length in feet.	Loss of Head per foot. I.	Mean Vel. Ft. per sec. V.	Name of Author and Description of Pipes.
			SERIES No. 11.		DARCY.
80	.2710	365.1	.00027	.328	
81	"	"	.00066	.577	
82	"	"	.00203	1.171	
83	"	"	.00629	2.182	
84	"	"	.01220	3.117	
85	"	"	.02285	4.442	Covered with Bitumen. New Pipe.
86	"	"	.03107	5.292	
87	"	"	.04070	6.148	
88	"	"	.07170	8.438	
89	"	"	.10654	10.535	
90	"	"	.13880	12.034	
91	"	"	.15605	12.786	
			SERIES No. 12.		DARCY.
92	.6430	365.3	.0002	.591	
93	"	"	.00048	.912	
94	"	"	.00129	1.529	
95	"	"	.0033	2.559	
96	"	"	.00580	3.530	
97	"	"	.0119	5.436	Covered with Bitumen. New Pipe.
98	"	"	.0120	5.509	
99	"	"	.0210	7.411	
100	"	"	.0297	9.000	
101	"	"	.0364	10.013	
102	"	"	.12156	19.72	
			SERIES No. 13.		HAMILTON SMITH, Jr.
103	1.056	684.9	.03318	10.706	Coated with Asphaltum and Coal Tar. About five years in use.
104	"	699.6	.02219	8.646	
105	"	709.2	.01428	6.962	
106	"	718.4	.00668	4.595	
			SERIES No. 14.		HAMILTON SMITH, Jr.
107	1.230	684.4	.03231	12.090	Coated with Asphaltum and Coal Tar. About five years in use.
108	"	695.6	.02470	10.593	
109	"	705.0	.01646	8.462	
110	"	710.7	.01227	7.314	
111	"	712.4	.01097	6.841	
112	1.229	719.9	.00502	4.383	
			SERIES No. 15.		
113	1.416	4438.7	.06672	20.143	"
			SERIES No. 16.		
114	2.154	1193.8	.01641	12.605	"
			SERIES No. 17.		
115	2.43	12798.	.01172	10.78	"


LOGARITHMIC HOMOLOGUES
FOR
NEW CAST-IRON PIPES.
LOGARITHM OF V.
LOGARITHM OF I.
I ∝ V1.88
1.88
D = 4.0
D = 1.64
D = 1.375
D = 1.0
D = 0.6168
D = 0.4495
D = 0.2687
D = 0.164
D = 0.8268
I ∝ 1/D1.33
(1)
(2)
(3)
(4)
(5)
(6)
(7)
(8)
(9)



LOGARITHMIC HOMOLOGUES
FOR
RIVETED SHEET-IRON PIPES
LOGARITHM OF I.
LOGARITHM OF V
(10)
(11)
(12)
(13)
(14)
(15)
(16)
(17)
D=0.0879
D=0.271
D=0.643
D=1.056
D=2.154
D=2.43
180

These experiments, with the exception of Series 5 and 6, which have been taken from M. Flamant's paper, are very fully described by Hamilton Smith, Jr., in his "Hydraulics," and by other authors. Hence, an extended description of them is not required here.

The experiments have been plotted on Plates 1 and 2 and are designated by their series numbers. The method used in plotting the results is that of logarithmic homologues, described by Professor Reynolds in his paper, previously referred to. For each observation the logarithm of I is plotted as an abscissa, and the logarithm of V as an ordinate. Then, if it be true that $I \propto V^n$, all of the experiments on the same pipe will fall in a straight line. The inclination of the line, or, in other words, the ratio of the base to the perpendicular of the slope, gives the value for the exponent n.

One advantage of this method is that the exponent n of V, thus found, can be used as a measure of the roughness of the surface, giving a scale by means of which pipes, having surfaces of different degrees of roughness, can be classified.

On Plate 1, the logarithmic homologues have been plotted for new cast-iron pipes. Each experiment is represented by a dot, and all of the experiments on the same pipe have been connected by a heavy full line. The numbers refer to the series, as given in the tables. It will be noticed that, in general, the lines connecting the experiments are very nearly straight and parallel. There are at times quite marked departures from this rule in some of the lines, but they are only temporary, and the line again returns to its general direction. As there is no regularity about these departures, it appears that they are due to experimental error, and not to any change of law. It will be noticed that the departures are more frequent with the low velocities. This may be due in part to the fact discovered by Professor Reynolds, that for very low velocities the flow of water takes place in parallel lines without eddies, and obeys the Poiseuille law of flow in capillary tubes; and that when the velocity of Stream $\times$ Width of Stream $\div$ Viscosity has reached a certain critical value, the stream breaks up into eddies, and the movement is like that in a wide tube. In the neighborhood of this critical velocity the flow is unsteady.

From Plate 1 it appears that all of the experiments can be very closely represented by straight dotted lines inclined at a slope of 1.88 to 1. The variation of I with V for new cast-iron pipes can therefore be closely represented by the form $I \propto V^{1.88}$. The variation of I with the diameter is obtained by plotting as ordinates the logarithms of the diameters, and as abscissas the logarithms of I corresponding to $V = 1$. The latter are found from the points of intersection of the dotted lines with the horizontal line corresponding to the logarithm of $V = 1$. The points obtained in this manner are shown by the circles on the plate.

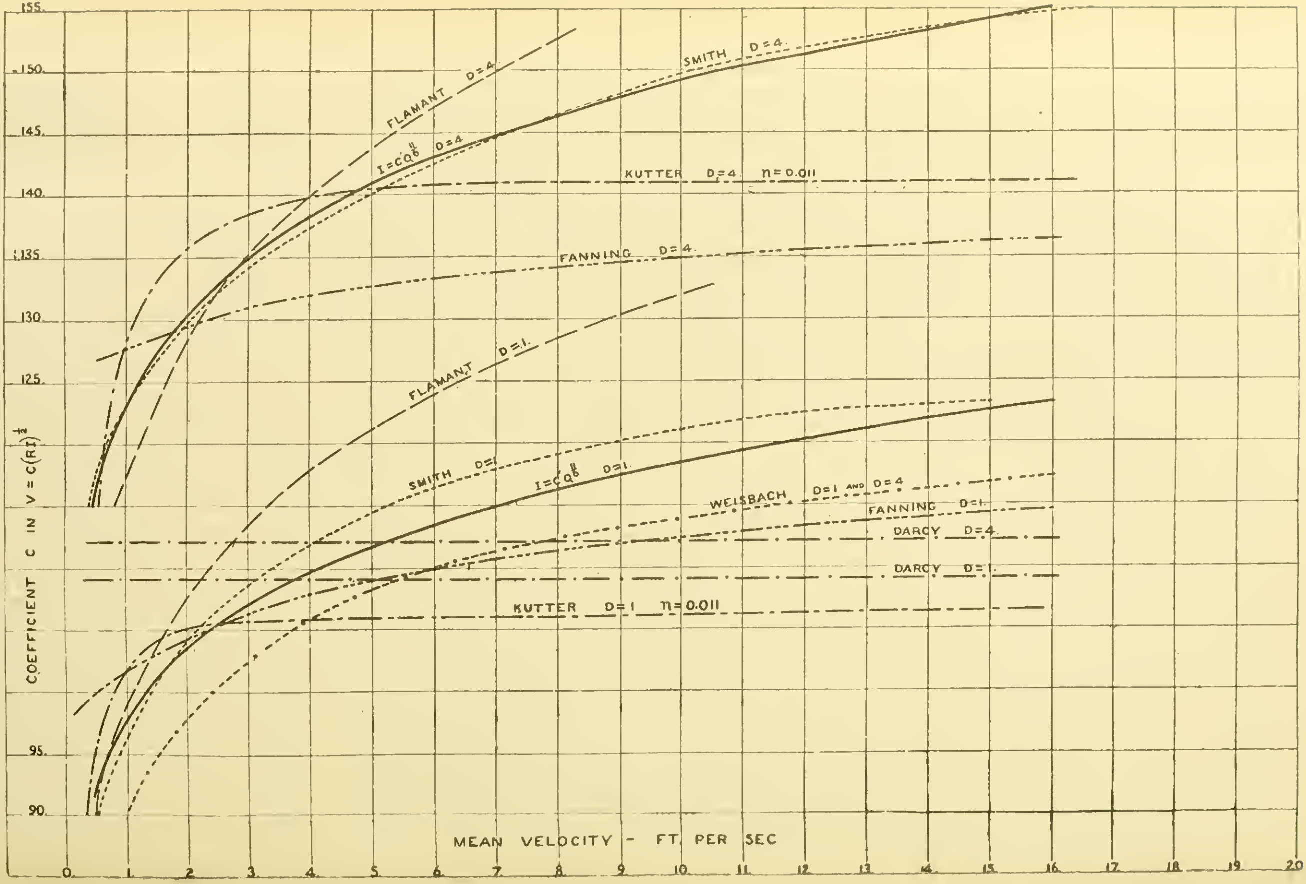
It will be noticed that in general they approach the straight dotted line drawn on the plate at a slope of 1.33 to 1, giving $I \propto \frac{1}{D^{1.33}}$. This gives for new cast-iron pipes the form $I \propto \frac{V^{1.86}}{D^{1.33}}$. The same analysis applied to the experiments on riveted sheet-iron pipes, Plate 2, gives the form $I \propto \frac{V^{1.80}}{D^{1.16}}$ as agreeing best with the experiments. It will be noticed that Series 15, 16 and 17, plotted on this plate, consist each of but one observation. It has been assumed that the variation of I with $V^{1.80}$ found from the other experiments applies to these; the reason for this being that a greater number of points was required to establish the variation of I with the diameter, and as they are experiments by Hamilton Smith, Jr., they were considered as entitled to weight.

$I \propto \frac{V^{1.833}}{D^{1.33}}$ was adopted as a general form, applicable, nearly enough for practice, to both classes of pipes. The value $V^{1.833}$ is approximately a mean of the two values found from the plates. The value $D^{1.33}$, obtained for cast-iron pipes, has been adopted because it leads to greater simplicity, and because the variation of I with D, as determined from the riveted sheet-iron pipes, was somewhat unsatisfactory. Adopting the form $I \propto \frac{V^{1.833}}{D^{1.33}}$ we can write $I = b\,\frac{V^{1.833}}{D^{1.33}}$, b being a constant to be determined. When $V = 1$, and $D = 1$, then $I = b$. The logarithm of I corresponding to $V = 1$ and $D = 1$ can be found from the plate, and hence also the value of b. When $V = 1$, and $D = 1$ the logarithm of I for new cast-iron pipes is found to be $\bar{4}.580000$, giving $b = .0003802$. For riveted sheet-iron pipes, when $V = 1$ and $D = 1$, the logarithm of $I = \bar{4}.660000$, giving $b = .0004571$. The average of these is .0004186. The equation can then be written

$$I = .0004186\,\frac{V^{1.833}}{D^{1.33}} \quad \text{or} \quad I = .0004186\,\frac{V^{\frac{11}{6}}}{D^{\frac{4}{3}}}$$

For circular pipes, when running full, $V = \frac{4\,Q}{\pi\,D^2}$. Substituting this value for V, and reducing, we have $I = \frac{.00065}{D^5}\,Q^{\frac{11}{6}}$; and, putting $C' = \frac{.00065}{D^5}$, we have $I = C'\,Q^{\frac{11}{6}}$.

It is very easy to solve problems of flow in pipes by the use of logarithms with this formula. By means of two short tables, one giving the values of $Q^{\frac{11}{6}}$ corresponding to ordinary discharges, and the other giving the values of C' for all of the usual diameters, the formula may be easily applied without the use of logarithms. Such tables are herewith presented. See Tables 1 and 2.



SMITH D=4.
FLAMANT D=4.
I=CQ^11/6 D=4
KUTTER D=4 n=0.011
FANNING D=4.
FLAMANT D=1.
SMITH D=1
I=CQ^11/6 D=1.
WEISBACH D=1 AND D=4
FANNING D=1.
DARCY D=4.
DARCY D=1.
KUTTER D=1 n=0.011
COEFFICIENT C IN V = C(RI)^1/2
MEAN VELOCITY - FT. PER SEC
155.
150.
145.
140.
135
130.
125.
95.
90.
0.
1.
2
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15.
16.
17.
18.
19.
20

For purposes of comparison, this formula, together with several others in frequent use, has been reduced to the Chezy form, $V = c\,(R\,I)^{\frac{1}{2}}$. The coefficients ($c$) thus obtained for pipes having diameters of 1 foot and 4 feet, have been plotted on Plate 3 as ordinates, with the mean velocity in feet per second as abscissas.

From the close agreement of the new formula with Hamilton Smith's conclusions, and with the results obtained from Kutter's formula for low velocities, it was thought that the formula reduced to the form $V^{\frac{11}{6}} = C\,R^{\frac{4}{3}}\,I$, could be used for calculating the velocity in channels having surfaces corresponding to Kutter's values of $n = 0.011$, C having a value of 15000.

In order to adapt these formulas to pipes and channels having surfaces of other degrees of roughness, the classification of surfaces adopted by Kutter has been followed. Values of C and C', based on Kutter's results and corresponding to his values for n, have been deduced. They are given in Table 4.

It was found that for channels having surfaces rougher than $n = .017$, the formula $V^2 = C\,R^{\frac{4}{3}}\,I$ agrees better with Kutter's formula than does that given above.

This modification is in accordance with the results of the experiments previously mentioned, which showed that with the rougher surfaces the value of the exponent n should be 2. Additional tables are not required by this modification, for a table of squares is usually at hand, and even if it is not the solution is very simple.

The formulas for flow in channels are easily applied by the use of logarithms. By means of a table giving values of $R^{\frac{4}{3}}$ (see Table 3), and by substituting V for Q in Table 1, the formulas are easily applied without the use of logarithms.

The following tables have been prepared for practical use.

In conclusion I wish to acknowledge my obligation to Mr. Desmond FitzGerald, member of this Society, for many valuable suggestions.

Notes on the Tables for Practical Use.

PIPES.

$$I = C'\,Q^{\frac{11}{6}}$$

I = friction head in feet per foot.

C' = a coefficient varying with the roughness and the diameter.

Q = discharge in cubic feet per second.

D = diameter in feet.

With Q or D given, find $Q^{\frac{11}{6}}$ or C' from tables 1 and 2, or *vice versa*.

Two of the quantities I, $Q^{\frac{11}{6}}$ and C' being known, the third can be found by multiplication or division.

NOTE: Values of $C' \left(= \frac{.00065}{D^5}\right)$ in table 2 are for coated, new, cast-iron and riveted sheet-iron pipes when running full. The formula can be used for circular conduits when running full, and for pipes of other degrees of roughness, by first multiplying C' by the proper number found in the last column of Table 4.

CHANNELS.

$V^{\frac{11}{6}} = C\,R^{\frac{4}{3}}\,I$ for surfaces corresponding to Kutter's values of **n*** = 0.009 to 0.017.

$V^2 = C\,R^{\frac{4}{3}}\,I$ for surfaces corresponding to Kutter's values of **n** = 0.020 to 0.035.

V = mean velocity in feet per second.

C = a coefficient varying with roughness.

R = hydraulic mean radius = $\frac{\text{area}}{\text{wetted perimeter}}$

I = sine of inclination.

Find $R^{\frac{4}{3}}$ from Table 3, and C from Table 4.

Having $V^{\frac{11}{6}}$, to find V; or, having V, to find $V^{\frac{11}{6}}$, use Table 1, substituting V for Q.

TABLE 1.

Discharge. Gallons per Min.	Discharge. Cubic ft. per Second. Q	$Q^{\frac{11}{6}}$	Discharge. Gallons per Minute.	Discharge. Cubic ft. per Second. Q	$Q^{\frac{11}{6}}$	Discharge. Gallons per Minute.	Discharge. Cubic ft. per Second. Q	$Q^{\frac{11}{6}}$
4.5	0.01	0.000 2	269.	0.60	0.39	2 692.	6.	26.
9.0	.02	.000 8	292.	.65	.45	3 142.	7.	35.
13.5	.03	.001 6	314.	.70	.52	3 590.	8.	45.
18.0	.04	.002 7	337.	.75	.59	4 039.	9.	56.
22.4	.05	.004 1	359.	.80	.66	4 488.	10.	68.
26.9	.06	.005 7	404.	.90	.82	4 937.	11.	81.
31.4	.07	.007 6	449.	1.00	1.00	5 386.	12.	95.
35.9	.08	.009 7	494.	1.1	1.19	6 283.	14.	126.
40.4	.09	.012 1	539.	1.2	1.40	7 181.	16.	161.
44.9	.10	.014 6	583.	1.3	1.62	8 078.	18.	200.
53.8	.12	.020 5	628.	1.4	1.85	8 976.	20.	242.
62.8	.14	.027 2	673.	1.5	2.10	9 873.	22.	289.
71.8	.16	.034 7	718.	1.6	2.37	11 220.	25.	365.
80.8	.18	.043 1	808.	1.8	2.94	13 464.	30.	511.
89.7	.20	.052	898.	2.0	3.56	15 708.	35.	677.
98.7	.22	.062	987.	2.2	4.24	17 952.	40.	865.
107.7	.24	.073	1 077.	2.4	4.98	20 196.	45.	1 074.
116.7	.26	.085	1 167.	2.6	5.76	22 440.	50.	1 302.
125.7	.28	.097	1 257.	2.8	6.60	26 928.	60.	1 819.
134.6	.30	.110	1 346.	3.0	7.5	31 416.	70.	2 414.
1 7.0	.35	.146	1 571.	3.5	9.9	35 904.	80.	3 083.
179.5	.40	.18	1 795.	4.0	12.7	40 392.	90.	3 826.
201.9	.45	.23	2 020.	4.5	15.8	44 880.	100	4 641.
224.4	.50	.28	2 244.	5.0	19.1	67 320.	150.	9 761.
246.8	.55	.33	2 468.	5.5	22.8	89 760.	200.	16 540.

*See "Trautwine's Pocket Book," p. 274.

TABLE 2.

DIAMETER. Ins.	DIAMETER. Feet. D.	C′	DIAMETER. Ins.	DIAMETER. Feet. D.	C′	DIAMETER. Ins.	DIAMETER. Feet. D.	C′
4	.33	0.158	12	1.00	0.000 65	30	2.50	0.000 0067
6	.50	.020 8	16	1 33	.000 154	36	3.00	.000 0027
8	.67	.004 94	20	1.67	.000 0506	40	3.33	.000 0016
10	.83	.001 62	24	2.00	.000 0203	48	4.00	.000 0006

TABLE 3.

R	$R^{\frac{1}{3}}$	R	$R^{\frac{1}{3}}$
0.1	0.05	1.5	1.72
.2	.12	2.0	2.52
.3	.20	2.5	3.39
.4	.29	3.0	4.33
.5	.40	3.5	5.31
.6	.51	4.0	6.35
.7	.62	5 0	8.55
.8	.74	6.0	10.90
.9	.87	7 0	13.39
1.0	1 00	8.0	16.00
1.2	1.27	10.0	21.54

TABLE 4.

KUTTER'S n.	C	MULTIPLY C′ BY
0.009	23 000.	0.65
.010	19 000.	0.80
.011	15 000.	1.00
.012	12 000.	1.25
.013	10 000.	1.50
.015	8 000.	1.90
.017	6 000.	2.50
.020	5 000.	
.025	3 000.	
.030	2 000.	
.035	1 500.	

THE GRAPHICAL SOLUTION OF THE DISTORTION OF A FRAMED STRUCTURE.

By David Molitor, U. S. Asst. Engr., Member of the Engineers' Club of St. Louis.

[Read May 16, 1894.]

INTRODUCTORY REMARKS.

1. The determination of the distortion of a framed structure is a problem frequently met with, both in the design and in the erection of bridges. In the recent publication, "Modern Framed Structures," by Messrs. Johnson, Bryan and Turneaure, it is fully treated in accordance with the analytical method of Prof. Mohr, of Stuttgart, and we now proceed to consider a graphical method, which, it is believed, will be found more satisfactory.

This graphical method, originally made known by Williot, and more fully treated by Prof. Culmann, would certainly demand place in a treatise on "Modern Framed Structures," since it is as accurate and as expeditious as any method now known. When once applied the problem is completely solved for every point of a framed structure, whereas the analytical method must be applied separately for each point whose displacement is desired. Furthermore, the analytical method gives only *vertical* deflections.

DERIVATION OF THE METHOD.

2. *Statement of the problem.* Having given the lengths, cross-sections and stresses of all the members of a framed structure, to find the changes produced in the lengths of these members and the resulting displacements of all the pin-points.

This is the most general form of the problem which it is here proposed to solve graphically. It is assumed that the members of the framed structure are in one and the same plane and that the elasticity of the material of the structure is known. Changes in the lengths of members, due to a change in temperature, may be included, as well as those due to loading and camber.

3. *To find the changes in the lengths of the members.*

Let l = the length of a member, in inches.

$\triangle l$ = the change in the length of this member, in inches, positive for elongation.

a = the cross-section of the member, in square inches.

s = the stress in the member, in pounds, positive for tension.

E = the modulus of elasticity of the material = 29,000,000 pounds per square inch for soft steel.

t = a given change of temperature, in degrees.

c = linear coefficient of expansion, being the expansion in inches due to an increase of 1 degree in temperature.

$$\text{Then } \triangle l = \frac{s\,l}{a\,E} + c\,t\,l.$$

The $\triangle l$ for each member of the structure may thus be found from the given data, and the solution of the second part of the problem can now be taken up.

4. *To find the distortion, or the change in the form, of a framed structure, resulting from changes in the lengths of its members.*

The simplest framed structure is one generated by successively adding members on to a triangle $a\,b\,c$ (Fig. 1) so that every pair of such additional members, as $c\,d$ and $b\,d$, will fix a new point d.

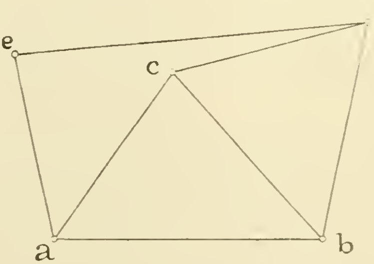


FIG. 1.

If, in Fig. 1, the change in the form of the triangle $a\,b\,c$ is determined, then the position of any other point d, of this structure can be found in the same way.

Suppose now that, in Fig. 2a, the point c be connected with the points a and b by the members 1 and 2, and that the lengths of these members are changed by $-\triangle 1$ and $+\triangle 2$ respectively, while the points a and b move to the positions a' and b'. Let it be required to find the direction and amount of the displacement of the point c.

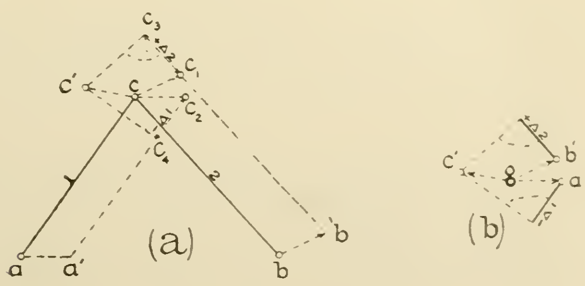


FIG. 2.

Assume the member 1 moved parallel to itself until a falls in a', likewise move the member 2 parallel to itself until b falls in b'. Now change the length of 1 by $- \triangle 1$ and the length of 2 by $+ \triangle 2$, or, in Fig. 2 a, subtract the shortening $\triangle 1 = c_2 c_4$ from $a' c_2$ and add the lengthening $\triangle 2 = c' c_3$ to $b' c'$. Now, with a' and b' as centers, and with radii equal to the new lengths, $a' c_4$ and $b' c_3$ respectively, of the members 1 and 2, describe arcs. The intersection of these arcs will give c', the new position of the point c. But, since these arcs are always very small compared with the lengths of the members, they may be assumed as being replaced by their tangents $c_3 c'$ and $c_4 c'$ respectively, which are drawn perpendicular to the original directions of the members. In Fig. 2 a, the displacements are shown several thousand times larger than they would appear if plotted to the same scale as the members $a c$ and $b c$.

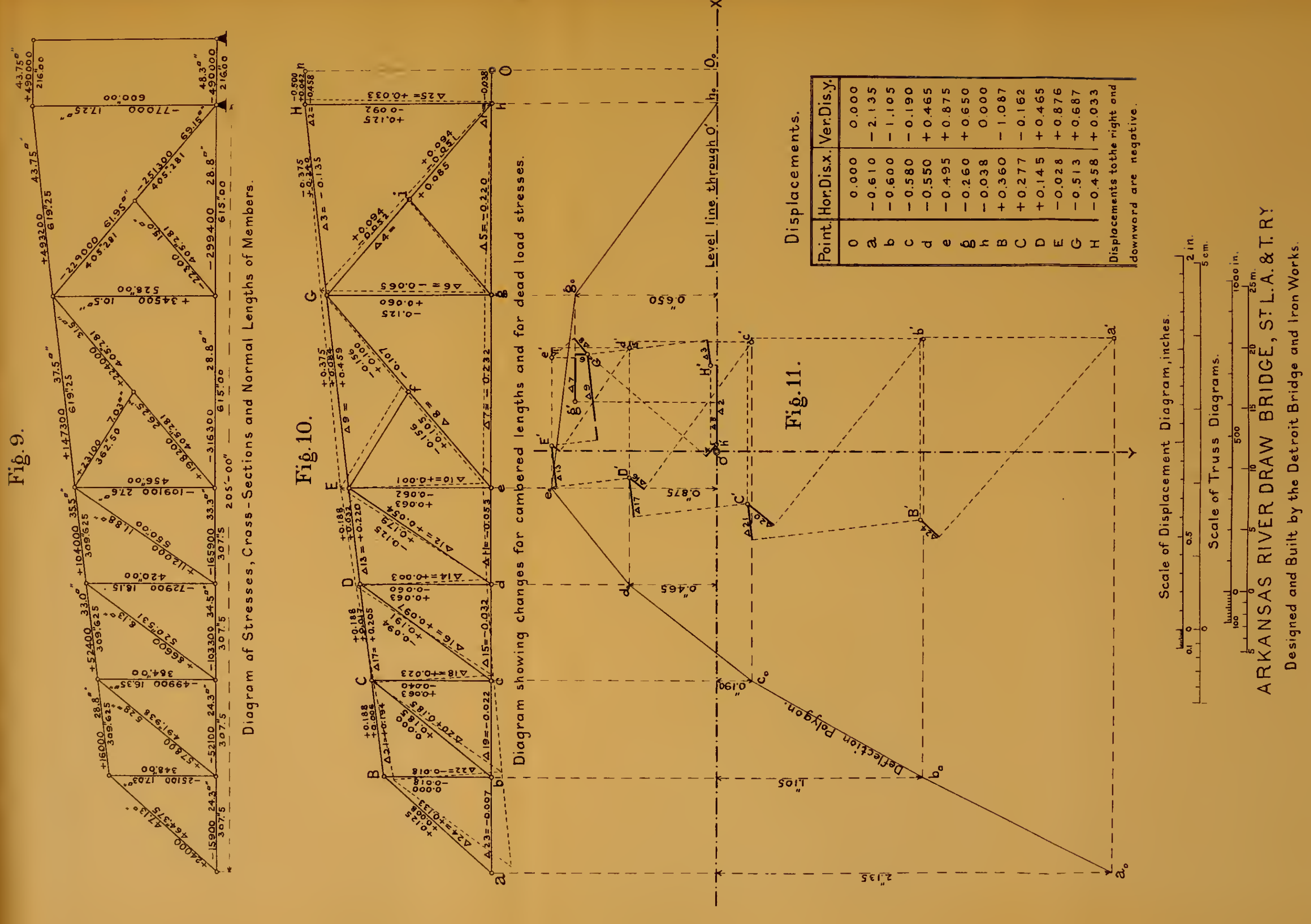
It is clear that the point c' might have been determined in a separate figure, as in Fig. 2 b, without drawing the members themselves, by dealing exclusively with the *changes* in the lengths of these members. The $\triangle l$'s are here plotted on a very large scale, affording greater accuracy in the results.

If the point o is regarded as a fixed point or pole, and if from this point the displacements of the points a and b are drawn, making $o a' = a a'$ and $o b' = b b'$ both in direction and in amount, then, applying at a' the change $(= - \triangle 2)$ in length of member 1, and at b' the lengthening $(= + \triangle 2)$ of member 2, and erecting perpendiculars at the extremities of $\triangle 1$ and $\triangle 2$, these perpendiculars will intersect in c', which is the new position of c. The displacement of c is then represented in direction and in amount by the line $o c'$.

In laying down the values of $\triangle l$ in Fig. 2 b the following rule respecting signs must be observed: If a' is regarded as fixed, then, since $- \triangle 1$ represents a *shortening* of $a c$, c moves in the direction from c *toward* a, and hence $- \triangle 1$ must be drawn from a' in the direction from c to a. Likewise, if b' is fixed, since $+ \triangle 2$ represents a *lengthening* of $b c$, c moves *away* from b, and hence $+ \triangle 2$ must be drawn from b' in the direction of b to c.

Similarly we may solve any succession of triangles, such as that indicated in Fig. 1. It is necessary only to assume that one of the members, as $a b$, retains its direction, and that some point of $a b$, as a, remains fixed.

In the example, Fig. 3 a, it is assumed that the direction of $a b$ and the position of the point a remain unchanged. The point o, Fig. 3 b, is the assumed pole, and since the point a is fixed it must coincide with o in Fig. 3 b. Since the member $a b$ does not change its direction, $\triangle 1$ is drawn parallel to $a b$, and, since $\triangle 1$ is negative, it must be drawn in the



Displacements.

Point.	Hor. Dis. x.	Ver. Dis. y.
O	0.000	0.000
a	−0.610	−2.135
b	−0.600	−1.105
c	−0.580	−0.190
d	−0.550	+0.465
e	−0.495	+0.875
g	−0.260	+0.650
h	−0.038	0.000
B	+0.360	−1.087
C	+0.277	−0.162
D	+0.145	+0.465
E	−0.028	+0.876
G	−0.513	+0.687
H	−0.458	+0.033

Displacements to the right and downward are negative.

ARKANSAS RIVER DRAW BRIDGE, ST. L. A. & T. RY.

Designed and Built by the Detroit Bridge and Iron Works.

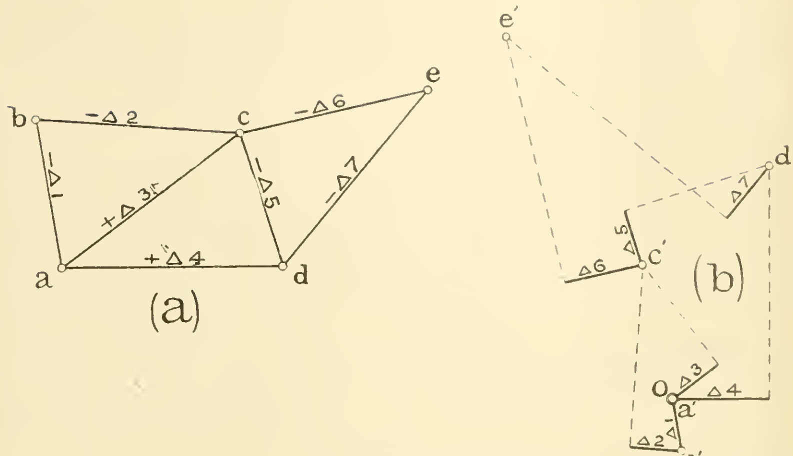


FIG. 3.

direction from b toward a. The displacement of b is thus given by $o\ b'$. The point c recedes from a by an amount $= \triangle\ 3$, and approaches b by an amount $= \triangle\ 2$. If, therefore, $\triangle\ 2$ is drawn from b' in the direction from c towards b and parallel to $c\ b$, and if $\triangle\ 3$ is drawn from o, or a', in the direction from a toward c and parallel to $a\ c$, then the intersection c' of the perpendiculars, erected at the extremities of $\triangle\ 2$ and $\triangle\ 3$, will be the new position of c. The displacement of c is thus given, both in direction and in amount, by $o\ c'$. The point d is connected with a and with c by the members $a\ d$ and $d\ c$, and its displacement $o\ d'$ is found by drawing $\triangle 4$ parallel to $a\ d$ from o in the direction $a - d$, and $\triangle\ 5$ parallel to $c\ d$ from c' in the direction $d - c$. The intersection d' of the perpendiculars to the extremeties of $\triangle\ 4$ and $\triangle\ 5$ is the new position of d. The new position e' of the point e is similarly found.

Fig. 3 b, whose polar distances $o\ b'$, $o\ c'$, $o\ d'$ and $o\ e'$ give the displacements of the points b, c, d and e, both in direction and in amount, is called the *displacement* diagram of the structure $a\ b\ c\ d\ e$, or, to give credit to its inventor, it may be called a Williot diagram.

5. *To find the displacements of the points of a rigid frame, resulting from a change in the position of one of its members.*

In the foregoing solution we assumed that the member $a\ b$ retains its direction. This may, or may not, be the case. If it is, then the displacements, as found in Fig. 3 b, are correct, but if this member ($a\ b$) changes its position, then a correction must be applied to the displacements already found. The method for applying these corrections is derived from the following principle in mechanics: *The motion of a rigid body, at any instant, may be defined as a rotation about a certain point called the instantaneous center of rotation; and the direction of mo-*

26

tion of any point of this body, at the instant in question, will be perpendicular to the line joining this point with the instantaneous center of rotation.

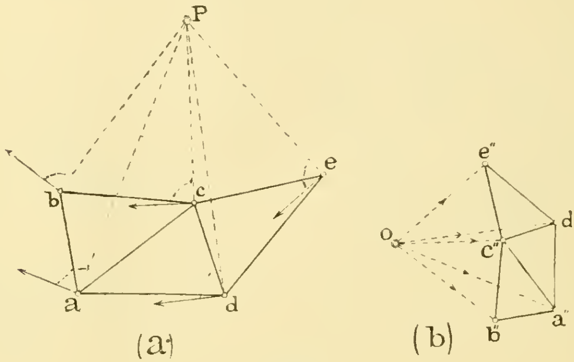


FIG. 4.

If, for instance, $a\ b\ c\ d\ e$, Fig. 4 a, is a rigid figure rotating about the instantaneous center P, each arrow will represent the direction of motion of its respective point; and if radial lines are drawn through a pole o, Fig. 4 b, and parallel to the arrows representing the motions, then these lines $o\ a''$, $o\ b''$, $o\ c''$, $o\ d''$ and $o\ e''$ will represent, both in direction and in amount, the displacements of the points a, b, c, d and e and the figure $a''\ b''\ c''\ d''\ e''$ will be the new position of the rigid frame $a\ b\ c\ d\ e$.

For, $a''\ o \perp a\ P$, $b''\ o \perp b\ P$, $c''\ o \perp c\ P$, etc., because the direction of motion of any point, a, of a rigid body is perpendicular to the line joining this point with the instantaneous center of rotation.

Also, $a''\ o$: $b''\ o$: $c''\ o$, etc. $= a\ P$: $b\ P$: $c\ P$, etc., because the displacements or motions of the points a, b, c, etc., are proportional to their velocities, and these in turn are proportional to the distances of the points from the instantaneous center of rotation.

From these conditions it follows that:

a. If the points a'', b'', c'', etc., of the displacement diagram, Fig. 4 b, are joined by straight lines, so that for every member $a\ b$ of the structure, there will be a corresponding line $a''\ b''$ in the displacement diagram, then these lines will produce a figure which will be similar to the rigid frame.

b. The line joining any two points of the rigid frame, as $a\ b$, will be perpendicular to the corresponding line $a''\ b''$ of the displacement diagram.

Hence, if it is possible to determine the positions of any two of the points a'', b'', c'', etc., of the displacement diagram then the figure $a''\ b''\ c''\ d''\ e''$ can be drawn by similarity with the figure $a\ b\ c\ d\ e$. The

method of determining the figure $a'' b'' c''$, etc., will be illustrated in the examples.

Therefore, the corrections by which we must modify the displacements shown in Fig. 3, in order to take into account the rotation of the side $a\,b$ about a, are found by inserting in the original displacement diagram a figure $a'' b'' c'' d'' e''$ similar to the figure $a\,b\,c\,d\,e$ and having its sides respectively perpendicular to the sides of this figure. The original displacements are then the distances $o\,b'$, $o\,c'$, etc.; the corrections are the distances $o\,b''$, $o\,c''$, etc., and the resulting displacements are the distances $b'' b'$, $c'' c'$, etc., always in the direction from b'' to b' c'' to c', etc.

The three steps in the process of finding the displacements of the pin-points of any framed structure, definitely supported, may then be outlined as follows:

a. In accordance with paragraph 4, assume as fixed the direction of a member and a point in the axis of this member, and construct the displacement diagram.

b. In accordance with the present paragraph, assume the structure as rigid, and consider this rigid frame subjected to a rotation such as will conform with the actual conditions of the supports.

c. The displacements may then be found, in direction and in amount, by scaling the distances between the m'' and m' points, the direction of the movement being always from m'' toward m'.

EXAMPLES.

6. The distortion of *a simple truss*, Fig. 5, has been solved in three ways, for the purpose of illustrating that the displacements are not affected by the choice of the member and point which are regarded as fixed in position, and also in order to show how to select the most convenient of the possible forms of solution.

The truss is supported on rollers at e and is fixed at a. The lengthenings (+) and shortenings (—) of the members are assumed to be as marked upon them.

The solution given in Fig. 5 *b* is made under the supposition that the direction of the member $a\,f$ and the point a remain fixed.

According to the method outlined in paragraph 4, a Williot displacement diagram, with pole at o, is constructed. Since a is now supposed to remain fixed, the point a' coincides with o, and the displacements of the various points b, c, d, e and f are obtained by scaling the distances $o\,b'$, $o\,c'$, $o\,d'$ . . . . . . $o\,f'$.

In reality, however, the direction of the member $a\,f$ does not remain fixed, for the member revolves about the point a. Therefore, the displacements just found must be combined with those displacements $o\,b''$,

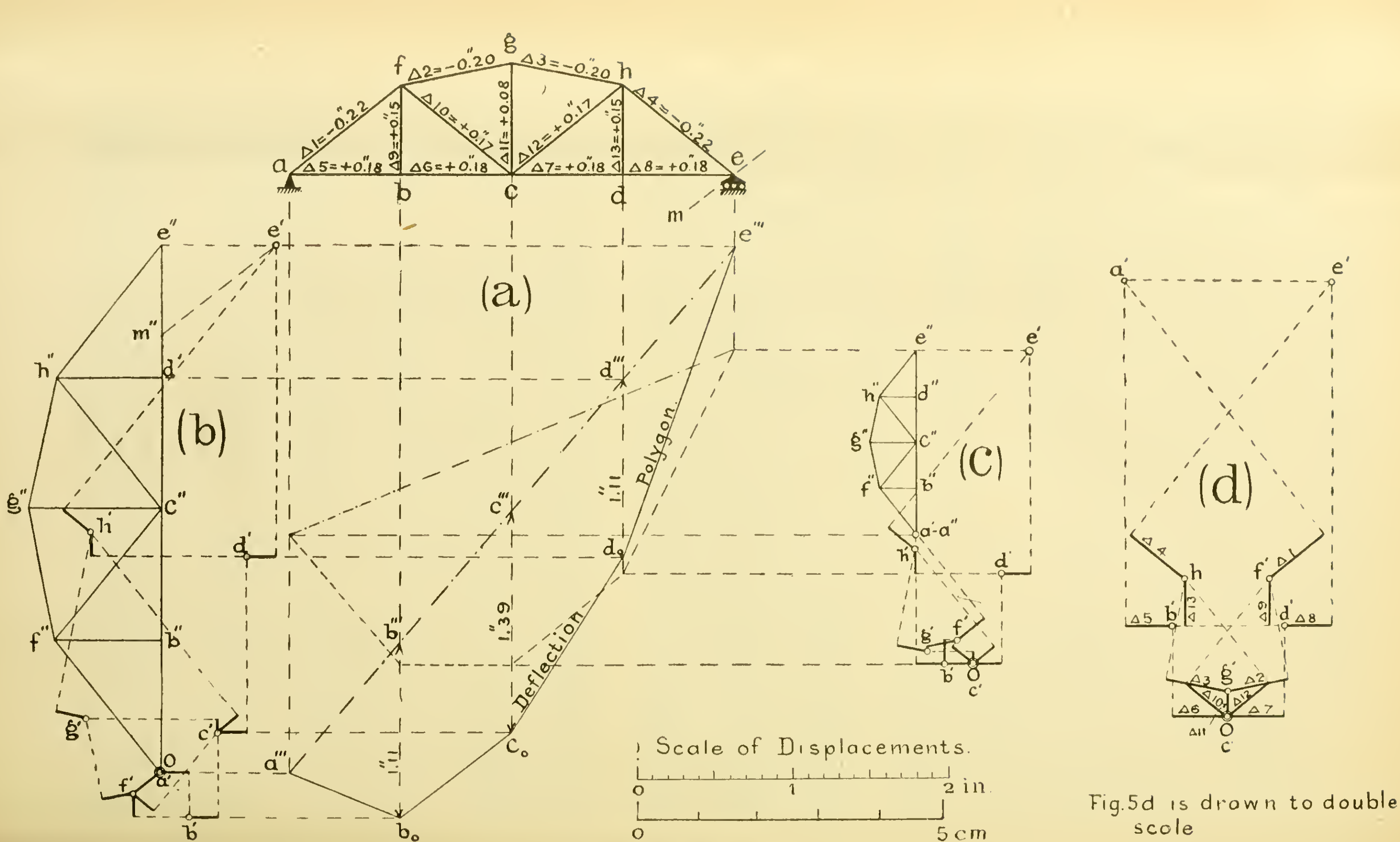

Δ1=−0.″22
Δ2=−0.″20
Δ3=−0.″20
Δ4=−0.″22
Δ5=+0.″18
Δ6=+0.″18
Δ7=+0.″18
Δ8=+0.″18
Δ9=+0.″15
Δ10=+0.″17
Δ11=+0.08
Δ12=+0.″17
Δ13=+0.″15
(a)
(b)
(c)
(d)
Deflection Polygon.
1.″39
1.″11
Scale of Displacements.
0
1
2 in.
5 cm
Fig.5d is drawn to double scale

Fig. 5

$o\,c''$, $o\,d''$, etc., which are caused by revolving the rigid frame, or truss, $a\,b\,g\,e$, about the point a, until the point e shows a resulting displacement, $e'\,e''$, parallel to the direction of motion of the roller bed at e.

In other words, the resultant movement of the point e will be horizontal when the roller bed is horizontal. If the bed were inclined, as *em* Fig. 5, then the point e would move parallel to $e\,m$.

The figure $a''b''c''d''e''f''g''h''$, similar to the figure of the truss, can then be constructed in accordance with paragraph 5, making the sides respectively perpendicular to the members of the truss. This figure is definite and can be drawn when the points a'' and e'' are found. These points are found as follows: The point a'' will coincide with a' or o, since it remains fixed, and $a''e''$ will be perpendicular to $a\,e$. Also $e'\,e''$ will be parallel to the roller bed, which is horizontal in the present case, but may be in any direction, as $e'm''$, for a skew-back.

The actual displacements of the points b, c, d, etc., will then be given in direction and in amount by the distances $b''b'$, $c''c'$, $d''d'$, etc., but the horizontal and vertical projections of these displacements are more generally desired.

The deflection polygon of the bottom chord is also found graphically by projecting the points a', a'', b', b'', etc., on to the verticals through the panel points a, b, etc. The points a'', b'', c'', etc., will be projected in a''' b''', c''', etc., and will form a straight line $a'''e'''$. The points b', c', d', etc., will fall in b_0, c_0, d_0, etc., and the ordinates $b_0\,b'''$, $c_0\,c'''$, etc., will give the vertical deflections of the panel points b, c, etc.

In Fig. 5 *c*, we assume the direction $c\,b$ and the point c fixed. All that has been said regarding the first solution applies here also. It will be seen that this solution gives exactly the same displacements as previously found, while it occupies only about half the space of the first diagram because the member $b\,c$ has a less angular motion than the member $a\,f$.

The third solution, Fig. 5 *d*, is the simplest of all, and its diagram covers the least area; for the member $c\,g$, which is now assumed as fixed, really has no angular motion, but simply drops vertically. The relative displacement $b'g'$ of any two points, b and g, may be scaled off directly. Although the displacement diagram was drawn on the assumption that the line $c\,g$ and the point c remained fixed, we are nevertheless at liberty to compare any two points of Fig. 5 *d*. Hence, any point may be chosen as the origin of co-ordinates from which to scale the horizontal and vertical displacements of all other points relatively to this origin. Naturally the displacements desired would be those with respect to the point a, for this is the fixed point, giving for the point e a horizontal movement from a' to e'. All other points move to the right and down from their original positions by amounts which may be scaled from the diagram, taking a' for the origin.

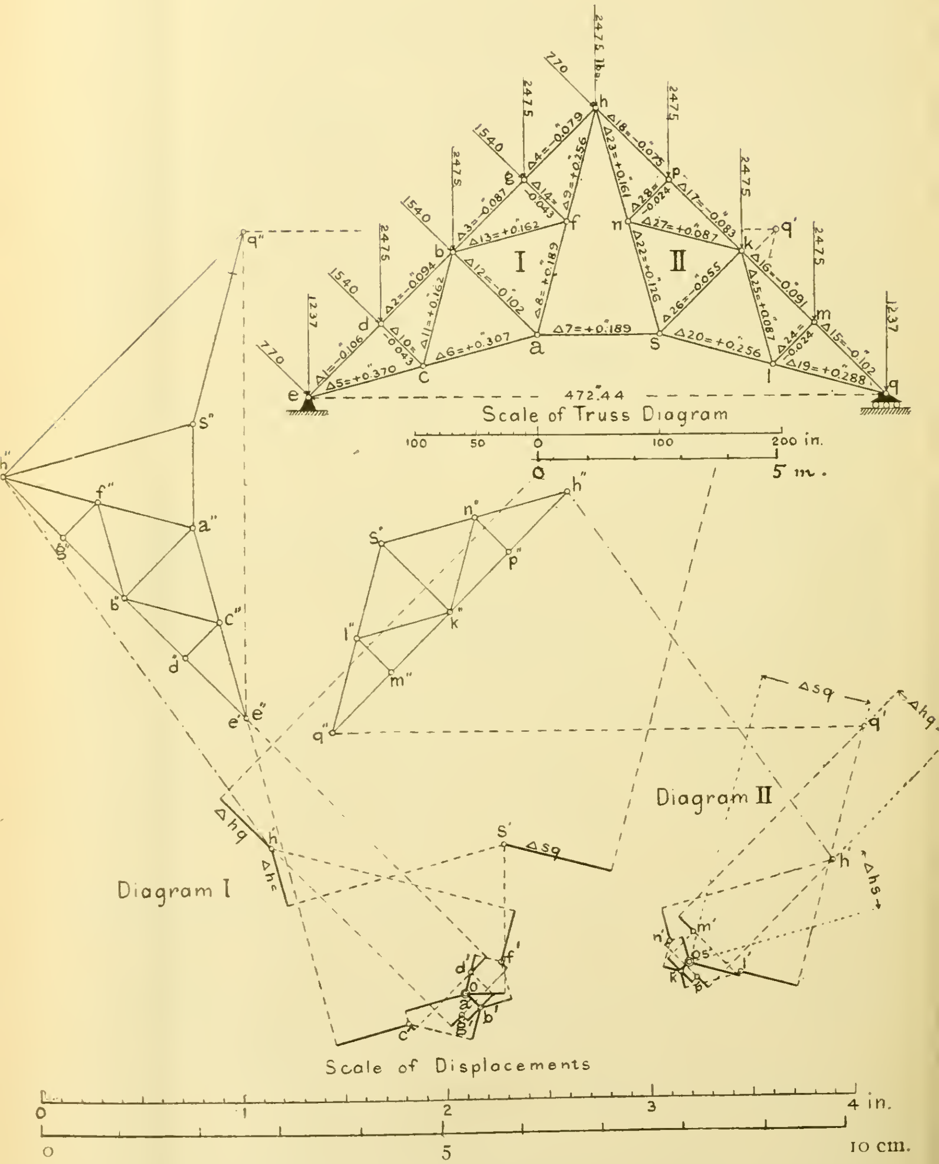

2475 lbs.
770
1540
2475
1237
Δ1=−0.106
Δ2=−0.094
Δ3=−0.087
Δ4=−0.079
Δ5=+0.370
Δ6=+0.307
Δ7=+0.189
Δ8=+0.189
Δ9=+0.256
Δ10=−0.043
Δ11=+0.162
Δ12=−0.102
Δ13=+0.162
Δ14=−0.043
Δ15=−0.102
Δ16=−0.091
Δ17=−0.083
Δ18=−0.075
Δ19=+0.288
Δ20=+0.256
Δ22=+0.126
Δ23=+0.161
Δ24=−0.024
Δ25=+0.087
Δ26=−0.055
Δ27=+0.087
Δ28=−0.024
I
II
472.44
Scale of Truss Diagram
100 50 0 100 200 in.
0 5 m.
Diagram I
Diagram II
Δhq
Δhs
Δsq
Scale of Displacements
0 1 2 3 4 in.
0 5 10 cm.

FIG. 6.

Hence it may be concluded, that if a truss contains a member which will move parallel to itself, or which has no angular motion, then this member is the best one to choose as the fixed member in constructing the displacement diagram. The second class of displacements, described in paragraph 5, is thereby eliminated.

7. *A roof truss*, Fig. 6.—In this example the stresses were found from a Maxwell diagram, and the corresponding changes in the lengths of the members were obtained by means of the formula:

$$\triangle\, l = \frac{s\, l}{a\, E},$$

taking E at 25,600,000 pounds per square inch for wrought iron. Changes of length due to temperature are neglected. The values of $\triangle\, l$ being very small, ten times these values were taken. All the data necessary in the solution of this truss are given in the following table:

TABLE OF THE VALUES OF s, a, l AND 10 $\triangle\, l$ IN FIG. 6.

Member.	Stress. lbs. s.	Area. sq. in. a.	Length. inches. l.	10 ($\triangle\, l$) inches.	Member.	Stress. lbs. s.	Area. sq. in. a.	Length. inches. l.	10 ($\triangle\, l$) inches.
1.	— 21800	6.82	83.53	— 0.106	15.	— 20970	6.82	83.53	— 0.102
2.	— 20040	6.82	83.53	— 0.094	16.	— 19210	6.82	83.53	— 0.091
3.	— 18300	6.82	83.53	— 0.087	17.	— 17470	6 82	83.53	— 0 083
4.	— 16540	6.82	83.53	— 0.079	18.	— 15710	6.82	83.53	— 0.075
5.	+ 19730	2.02	96.53	+ 0.370	19.	+ 15330	2.02	96.53	+ 0 288
6.	+ 16430	2.02	96.53	+ 0.307	20.	+ 13570	2.02	96.53	+ 0.256
7.	+ 9040	1.86	100.08	+ 0.189	—	——	——	——	——
8.	+ 9260	1.86	96.53	+ 0.189	22.	+ 6200	1.86	96.53	+ 0.126
9.	+ 12560	1.86	96.53	+ 0.256	23.	+ 7960	1.86	96.53	+ 0.161
10.	— 3300	1.40	48.07	— 0.043	24.	— 1680	1.40	48.07	— 0.024
11.	+ 3300	0.78	96 53	+ 0.162	25.	+ 1680	0.78	96.53	+ 0.087
12.	— 6600	2.48	96.53	— 0.102	26.	— 3520	2.48	96.53	— 0.055
13.	+ 3300	0.78	96.53	+ 0 162	27.	+ 1680	0.78	96.53	+ 0.087
14.	— 3300	1.40	48.07	— 0.043	28.	— 1680	1.40	48.07	— 0.024

The truss is composed of the two frames $a\, e\, h$ and $s\, q\, h$, designated I and II. These are connected by the member $a\, s$ and by the pin at h.

The displacement diagram of frame I is first drawn, assuming as fixed the direction of any member, as $a\, b$, and the position of a point, as a, of this member. The point a' then coincides with the pole o, and the displacement $o\, b'$, of the point b will be equal to $\triangle$ 12. The points c', d', e', f', g' and h' are then found as directed in paragraph 4.

The displacement diagram of frame II is next drawn, assuming as fixed the direction of the member $s\, k$ and the position of the point s.

Having thus determined the points k', l', m', q', n', p' and h' in diagram II, the relative changes in the positions of the points h, s and q, parallel to the straight lines joining the points h and s, h and q, and s

and q, may be found. These changes are called $\triangle\ h\ s$, $\triangle\ h\ q$ and $\triangle\ s\ q$.

Diagram I may now be completed by inserting the values $\triangle\ h\ s$, $\triangle\ h\ q$ and $s\ q$, previously found from diagram II. The point s' is found from $\triangle$ 7 and $\triangle\ h\ s$ and the point q' is found from $\triangle\ h\ q$ and $\triangle\ s\ q$. Since q moves on a horizontal roller bed and since e is fixed, the figure $c''\ d''\ b''\ g''\ h''\ f''\ a''\ s''\ q''$ can be drawn as in the preceding problem. This figure gives the displacements of all the points of frame I, and those of the points s and q.

The displacement diagram of frame II may now be completed by transferring the displacements of the points h and q from diagram I into diagram II, thus determining the points q'' and h'' from which the figure $q''\ l''\ s''\ n''\ h''\ m''\ k''\ p''$ can be drawn.

As a check, it should be remembered that the line $q''\ h''$ in diagram II must be perpendicular to the line $h\ q$, and that the displacement $s'\ s''$ of the point s must be the same, both in direction and in amount, in both diagrams.

Diagram II might have been dispensed with in the present case, as the values $\triangle\ h\ s$, $\triangle\ h\ q$ and $\triangle\ s\ q$ might have been found directly by summing the $\triangle\ l$'s. However, the use of diagram II is general, and it becomes necessary when the points h, p, k, m and q, or h, n and s, or l, s and q, are not in straight lines, as in the case of a curved top chord.

Measurements from diagram I show that the point g undergoes the greatest displacement, having a horizontal movement of $\frac{1.93}{10} = 0.193$ inch to the right, a vertical downward movement of $\frac{2.33}{10} = 0.233$ inch, or a resultant movement of $g'\ g'' = \frac{3.02}{10} = 0.302$ inch. The horizontal movement of the point q is $= q'\ q'' = \frac{2.61}{10} = 0.261$ inch. The displacements given by the diagram are here divided by 10, because, as already stated, the changes $\triangle\ l$ were originally, for convenience, taken ten times too large.

8. *A three-hinged arch*, Fig. 7.—It is required to draw the displacement diagram.

Independent diagrams for each of the elastic frames, I and II, are first drawn by assuming as fixed the direction of, and a point on, some member of each frame, as was done in the problem solved in paragraph 7.

The frames I and II are then regarded as rigid, and each frame is supposed to revolve in such a way as to satisfy the conditions imposed by the supports.

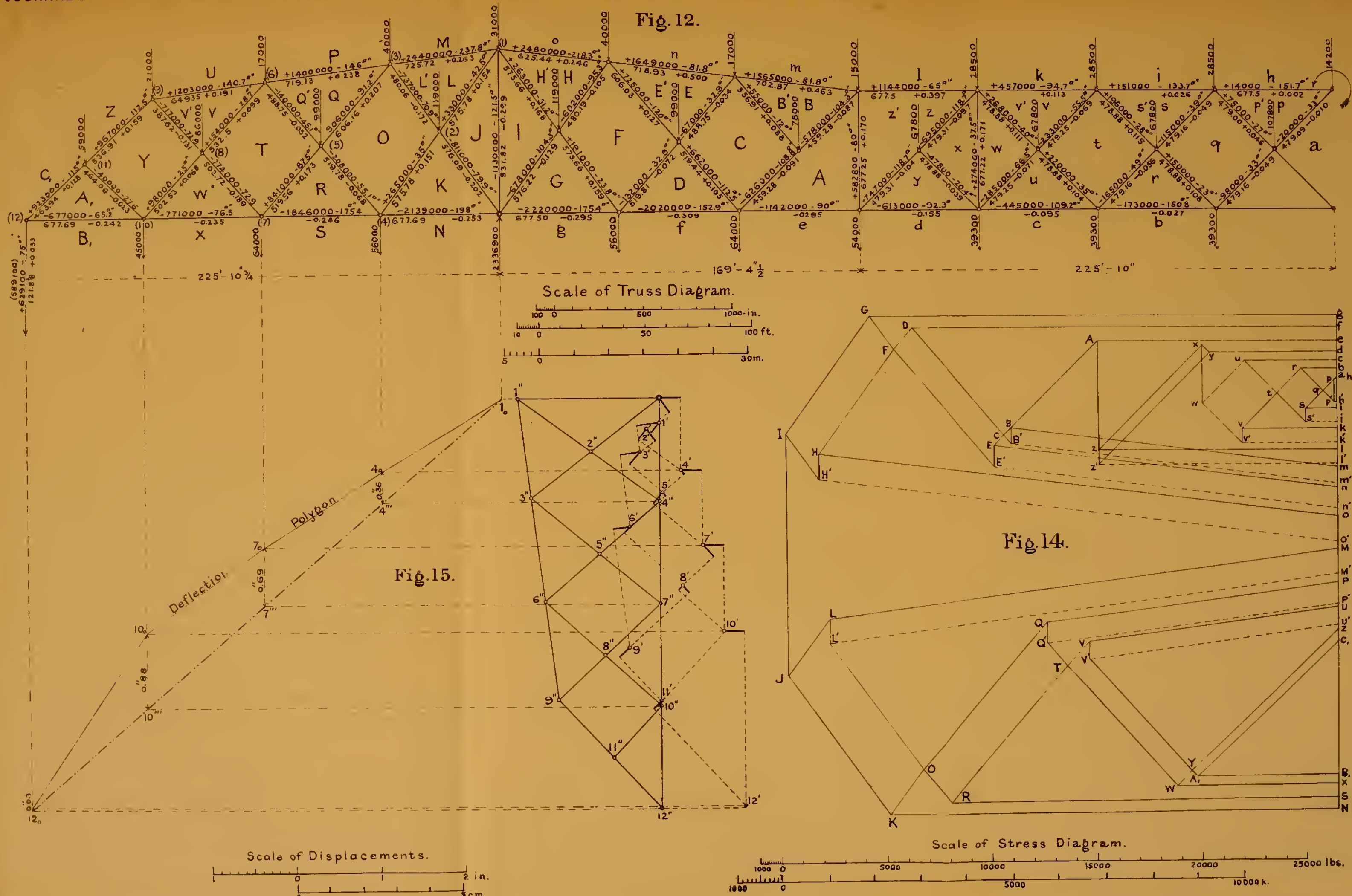


Fig. 12.

Fig. 14.

Fig. 15.

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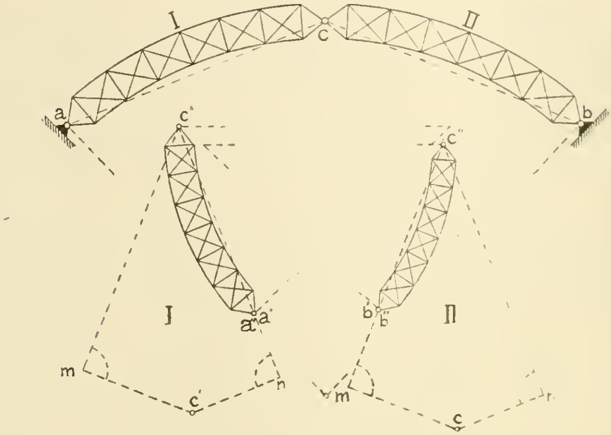

FIG. 7.

The displacement diagrams are omitted and only the second part of the problem is solved.

Supposing that the points a' and c' in Fig. 7, diagram I, and the points b' and c', diagram II, have been found from the corresponding displacement diagrams (not shown), let it be required to complete the diagrams in accordance with the principles laid down in paragraph 5.

The following conditions must exist between the figures $a'' c''$ and $b'' c''$, which are to be similar to the frames I and II respectively:

a. The displacement of the point a is zero, hence a'' will coincide with a'.

b. Similarly b'' will coincide with b'.

c. The line $a'' c''$ in diagram I must be perpendicular to the line $a\,c$.

d. The line $b'' c''$ in diagram II must be perpendicular to the line $b\,c$.

e. Both diagrams, I and II, must give the same displacement $c' c''$ for the point c.

Hence, $a'' c''$ is drawn through a', perpendicular to $a\,c$, also $b'' c''$ through b' perpendicular to $b\,c$. Now, in diagram I, $c' n$ is drawn parallel to $a\,c$, intersecting $a'' c''$ in n, and the projection of the required displacement $c' c''$, parallel to $a\,c$, is obtained. Likewise, in diagram II, $c' m$ is drawn parallel to $c\,b$, intersecting $b'' c''$ in m, giving $c' m$, the projection of $c' c''$ parallel to $c\,b$.

Diagram I may now be completed by transferring $c' m$ from diagram II and erecting a perpendicular to $c' m$ at m. This perpendicular will intersect $n\,a'' c''$ in c'', and the figure $a'' c''$ can now be drawn by similarity with the frame I, since the members in the two figures are respectively perpendicular.

In like manner diagram II may be completed by transferring $c' n$ from diagram I and drawing $n c''$ perpendicular to $c' n$, thus determining c''. As a check, the displacements $c' c''$ must be equal and parallel in the two diagrams.

9. *A cantilever*, similar in principle to the Memphis Bridge, is represented in Fig. 8.

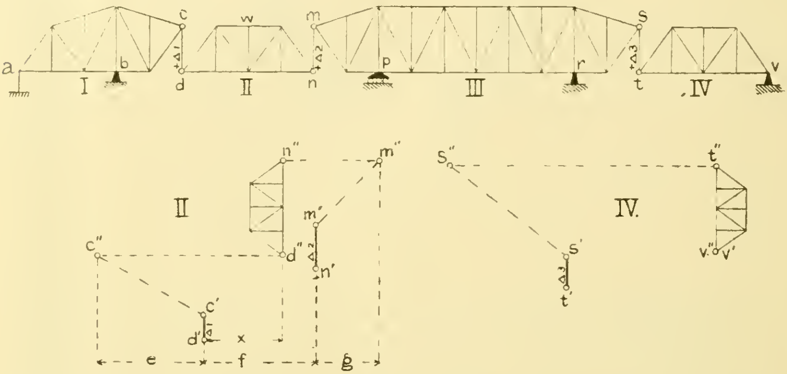

FIG. 8.

It is assumed, as in the two preceding problems, that separate displacement diagrams have been made for each of the elastic frames, I, II, III and IV, and of these, the diagrams for I and III can be completely solved, as was done with the example in paragraph 6, since each is a framed structure on two supports, one fixed and one movable.

It is here deemed necessary only to complete the displacement diagrams of the frames II and IV. The displacements of these frames depend respectively upon those of the points c and m, and upon that of the point s.

Let it be assumed that the points d' and n' have been determined for the elastic frame II as in diagram II, and let it be required to find the figure $d'' n''$ which shall be similar to frame II.

The members $c\,d$ and $m\,n$ are elongated by $\triangle 1$ and $\triangle 2$ respectively, and their elongations must be applied to the points d' and n' in diagram II, giving the points c' and m'. Now if the displacements $c' c''$ and $m' m''$ be drawn as found by diagrams I and III (not shown), the points c'' and m'' are obtained. These represent the original positions of the points c and m. The point n'' must have originally been at the same relative level with m''; also d'' must have been at the same relative level with c''. Lastly, the line $d'' n''$ must be perpendicular to $d\,n$. Hence, if the distance x, or the horizontal distance between d' and d'', can be found, then the figure $d'' n''$ becomes determinable and the diagram can be completed. If it is granted that the point w will always be midway

between the points c and m, this problem becomes definite, and the value x may be found from the figure, thus: $x = \frac{e - g + f}{2}$, which is (+) when measured to the right.

Assuming the displacement diagram of the frame IV drawn, and the points v' and t' determined, as shown in diagram IV, to find the figure $v'' t''$.

The point v is a fixed support, hence v'' must coincide with v', also the direction of $v'' t''$ must be perpendicular to $v t$. To find t'', apply $\triangle 3$ from t' to s', and then transfer the displacement $s' s''$ from diagram III (not shown) into diagram IV, thus giving the original position of s''. The point t'' must have dropped from the height s'', and must, therefore, be on the same horizontal line with s''. Hence, t'' is at the intersection of $v'' t''$ and the horizontal through s'', and the figure $v'' t''$, similar to the frame IV, can then be drawn.

10. *Arkansas River Draw Bridge, St. L. A. & T. Ry.* Figs. 9, 10 and 11 represent the complete solution of the distortion of this draw span when swung open and loaded with dead load.

This problem is frequently met with in practice in determining the amount of endlift to be provided.

The stresses, as determined for an assumed dead load of 1,135 pounds per foot per truss, are given in pounds by the figures written first in order over the members in Fig. 9, (+) indicating tension and (—) compression. The cross-sections of the members, in square inches, are written to the right of the stresses, and the normal lengths of the members, in inches, are written below the members.

Fig. 10 shows the changes in the lengths of the members. The upper figures represent the changes for the built or cambered lengths, the figures next below are the changes resulting from the dead-load stresses, as found from the data given in Fig. 9, and the resulting changes, or the $\triangle l$'s, are written below the lines. No temperature effects have been considered.

Fig. 11 shows the displacement diagram and the deflection polygon. In this example the simplest solution, as in Fig. 5 d' was chosen, avoiding thereby the second part of the problem, or that described in paragraph 5. This was accomplished by assuming as fixed the direction of the member $o\,h$ and the point o, an assumption which is in accordance with the facts; for the points o and n, being in the center of the span, must remain fixed horizontally; and o, being dependent upon the center support, will remain fixed vertically, if the elastic distortion of the turntable is neglected. Both the members $h\,o$ and $H\,n$ remain horizontal and $\triangle 1$ and $\triangle 2$ are the changes in their half lengths, respectively.

Fig. 11 is constructed in accordance with paragraph 4 and we have only to indicate the first steps.

The point o' is the pole, and, as o is the fixed point, o' must fall on this pole, and △ 1 is drawn horizontally, determining h'. Since n remains fixed horizontally, △ 2 is drawn from o' and △ 25 is drawn vertically from h'. The perpendiculars to the extremities of △ 2 and △ 25 give the point H'. The completion of the figure involves no operations that have not been described in paragraph 4.

The horizontal and vertical displacements of each panel point, with reference to its original position, are the horizontal and vertical distances between the pole o' and the point. These displacements have been scaled from the figure and tabulated on the drawing, expressed in inches.

Since the member $o\ h$ does not change its direction, and since, therefore, the second part of the problem does not come up for solution, the closing line of the deflection polygon becomes a horizontal line through the pole o', as it would have been in Fig. 5 *d*.

The distorted shape of the truss figure is shown in dotted lines in Fig. 10, where the co-ordinates are plotted to a scale = 30 times that of the truss diagram.

Through the kindness of the Detroit Bridge and Iron Works, I have obtained the levels taken on this draw-span, on completion of the work in 1891, by Mr. H. G. Kelley, Res. Eng'r. St. L. A. and T. Ry. A comparison of the vertical deflections of the bottom chord, as determined by leveling and by the present method, is given in the following table:

Panel Point.	Average Levels on Symmetrical Points.	Vertical Displacements as determined by Levels.	Graphically.
a.	218.765 feet.	—1.980 inches.	—2.135 inches.
b.	218.857 "	—0.876 "	—1.105 "
c.	218.932 "	+0.024 "	—0.190 "
d.	218.982 "	+0.624 "	+0.465 "
e.	219.005 "	+0.900 "	+0.875 "
g.	218.980 "	+0.600 "	+0.650 "
h.	218.930 "	0.000 "	0.000 "

The actual weight of the superstructure was 986,250 pounds = 1152 pounds per foot per truss. This exceeds the assumed load by 17 pounds per linear foot. The stresses were computed, assuming the dead load as uniformly distributed, while in reality the load per foot increases toward the center pier. The stresses thus obtained are considerably in excess, even though the assumed load was 17 pounds too small. This is clearly indicated by the above table of comparative deflections. Making allowances for these differences, and for a probable error in the shop lengths of the members, the result of the present investigation may be considered very satisfactory.

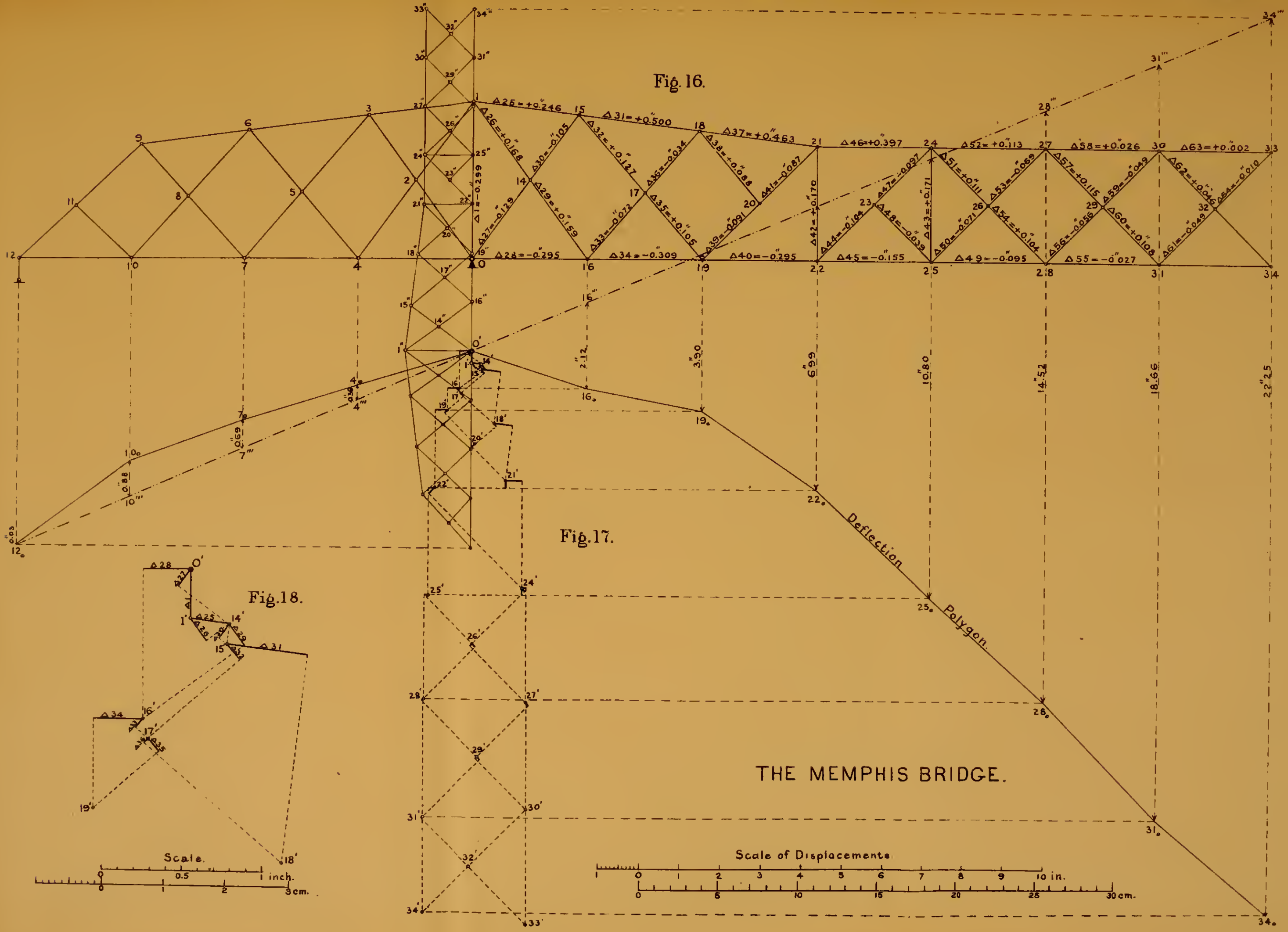
Fig. 16.
Fig. 17.
Fig. 18.
Deflection Polygon.
THE MEMPHIS BRIDGE.
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11. *The Memphis Bridge, at Memphis, Tenn.* Figs. 12 to 18 give the solution of a cantilever, such as would be necessary in adjusting the length of the intermediate or suspended span. The example chosen is the Tennessee half of the 790-foot cantilever span of the Memphis Bridge, built by the K. C. & M. Ry. & B. Co., Mr. Geo. S. Morison, Chief Engineer, and Mr. Alfred Noble, Resident Engineer.

Having had charge of the superstructure of this bridge during its erection in 1891–2, I have selected this as an interesting example of shose cases where the question of distortion becomes one of great importance.

Fig. 12 is a stress diagram, containing the stresses in the members, in pounds (as found from the Maxwell diagram, Fig. 14); the cross-sections, in square inches; and the lengths and changes in the lengths in inches.

The stresses are found for the assumed dead loads shown in Fig. 12. The changes for the cambered lengths of the members, and changes due to temperature, have not been considered, although it would have been necessary to consider them in solving an actual case. The temperature effect, however, might be approximated by treating the structure as a beam. This would probably be easier than to consider the effect on each member, but would neglect vertical displacements.

In the present structure there is no member which does not change its direction, and the point of support is the only point which remains fixed. Hence, in constructing the displacement diagram, we have taken as fixed the direction of the member IJ and the point of support. To avoid confusion of lines the anchorage span, to the left, is solved separately in Fig. 15, and the deflection polygon is transferred to Fig. 17. A portion of Fig. 17 is shown on a larger scale in Fig. 18.

It may be mentioned that it is not necessary to solve the double system in the displacement diagram. Having all the $\triangle l$'s, the solution of one system is sufficient to find the end points. This would be the usual way, as it is rarely necessary to obtain all the pin-points.

The problem here takes the general form, as in Fig. 5 b or 5 c, and requires no detailed explanation. The surprisingly large deflection of the point 34 represents the actual drop of this point below its cambered position, while the drop below the horizontal through the support can be determined by considering the changes in the cambered lengths of the members, as was done in the problem of paragraph 10.

The present example illustrates the general method of solving such a problem. The exact process to be followed must depend upon the particular purpose for which the investigation is made.

The examples, worked out in connection with this paper, are considered ample to make the method clear and to show its advantages over other methods.

THE CONTRIBUTION BOX.

Members of the associated societies, and other persons, are invited to send to the Secretary, for this department of the JOURNAL, such matters of general interest as may come to their notice.

Progress of the Metric System.

We are informed that a petition, signed by a large number of influential members of Parliament, has been presented to that body, praying for the appointment of a Select Committee to consider the desirability of adopting the metric weights and measures.

We note also that "the general adoption of the decimal system in calculations and accounts, and the general introduction of the metric system" is one of the subjects announced in the official list of those to be discussed at the 1895 meeting of the International Railway Congress.

The International Institute of Engineers and Architects.

Mr. Elmer L. Corthell, late Chairman of the General Committee on International Engineering Congress, whose suggestion looking to the formation of an International Institute of Engineers was mentioned in the February JOURNAL, has now formulated a proposition for this purpose.

The principal objects of the proposed Institute are the provision of a suitable channel for the international exchange of information respecting engineering and other works and discoveries, the conduct of tests of materials and the publication of the results of such tests through the channels of the Institute.

It is proposed to admit to fellowship in the Institute "any person engaged in the profession of engineering or architecture, of mature age and of good character." The governing bodies are to be National Boards of Direction, with an International Board of Direction and an International Executive Committee. The dues are fixed at ten dollars (or equivalent) per annum. The papers and discussions, after final approval by the Executive Committee of the International Board, are to be edited monthly and supplied to each fellow. The Institute is to be divided into eight divisions, corresponding to the departments of civil, mining and metallurgical, mechanical, electrical, marine and military engineering, engineering education and architecture. The proceedings are to be printed in English, French, German and Spanish, each fellow to be supplied with the proceedings in the language specified in his application for fellowship, or subsequently. Both metric and English measures are to be given in each paper and in the discussion. It is proposed that the general office and domicile of the International Board and of the Institute shall be in the United States, but the particular city is not specified. The first Congress of the Institute is to be held in Paris in 1900, and quintennial congresses are to be held thereafter, the place of each being determined at the one preceding it.

Mr. Corthell asks for comment and criticism upon these suggestions, and we shall be glad to receive them from our readers.

THE LIBRARY.

It is proposed to notice briefly in this department of the JOURNAL such engineering publications as may find their way to our shelves.

Publishers are requested, in sending works for review, to state the prices of same.

Public Works and Mines. THE TRADITIONS AND SUPERSTITIONS OF ALL COUNTRIES RESPECTING ——.* By PAUL SÉBILLOT, Ancien Chef du Cabinet, du Personnel et du Secrétariat au Ministère des Travaux Publics. Paris: J. Rothschild, 1894. 602 pages. 5½ by 8½ inches. Index, 21 pages. 413 figures in the text, 3 colored plates, and 8 plates with reproductions of medals.

Its illustrations alone would make this a highly interesting book. Like the letter-press, they are produced in most excellent style, and showing, as they do, the conceptions of all ages respecting what may be called the demonology of public works and of mines, they form, in themselves, a veritable treatise upon the subject. The author has made excellent use of his access to valuable collections of medals and engravings, and has placed the results before the reader with commendable liberality. Many of the illustrations are of Japanese origin, and display that highly artistic ability to show the expressions of things in a few masterly touches which characterizes the art work of that peculiar people.

The work is an almost bewildering compilation of traditions and proverbs referring to roads, bridges, canals, harbors, lighthouses and mines. Even that modern creation, the railroad, comes in for a share of the author's notice, but the treatment of this branch of the subject is made up rather of modern squibs and jokes than of tradition and superstition proper.

Brick for Street Pavements. By M. D. BURKE, C. E.

In reviewing this pamphlet for the May JOURNAL, the Librarian omitted to state that it is published by Messrs. Robert Clarke & Co., 61–65 West Fourth Street, Cincinnati, and that the price is 50 cents. The village of Avondale, for which the tests were made, is a suburb of Cincinnati.

Society Proceedings.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA. Proceedings of —. April, 1894, May, 1894.

This number, of 43 pages, contains the record of the meeting of April 19th, and presents two papers, one a short illustrated description of the manufacture of glass pipes of large calibre by the Appert process, by Mr. Francis C. Phillips, and the other a discussion of the theory of dynamic work applied to static forces, by James H. Johnson. Messrs. Emil Swensson and J. Deforth, in discussing the paper, claim that Mr. Johnson is laboring under some confusion of ideas, arising from lack of rigor in the definitions of his terms. The number concludes with a note, read by Mr. Francis C. Phillips before the chemical section and describing a form of silver obtained in the reduction of the sulphide by hydrogen.

* Les Travaux Publics et Les Mines dans les Traditions et les Superstitions de tous les Pays.

In the May number, of 34 pages, the discussion of Mr. Johnson's paper is continued by Mr. W. L. Scaife, Prof. Merriman, and Mr. F. C. Schellenberg; and Mr. William H. Blauvelt submits a paper on the Prevention of Smoke in Boiler-firing by the Use of Producer Gas.

American Institute of Electrical Engineers. Transactions of the ——. May, 1894.

This number, of 88 pages, opens with a discussion, by Dr. Otto A. Moses, of Prof. Anthony's paper on Incandescent Lamps. Dr. Moses refers to some experiments made by him for Mr. Edison, in the early days of electric lighting, upon the black deposit which coated the globes and which threatened to prove fatal to the use of such lamps. He claims that there is evidence of a continuous distillation of volatile portions of the hydrocarbon filament, until the limit is reached in the disintegration, or perhaps the volatilization, of the carbon. This, he believes, accounts for all the discordant phenomena brought out in the discussion.

Mr. Farnham's now classic paper on the electrolysis of water-pipes by means of the return circuits of trolley lines is discussed by Prof. Plympton, Mr. Kennelly, and others. Prof. Elihu Thomson recalls his investigations in this field in connection with the Boston roads, and holds that if every line of pipe could be made a perfect conductor, without bad joints, the problem of protection would be much simplified. He assures us that, during the present year, earnest efforts will be made to prove the practicability of laying continuous rails, electrically welded in place.

The number contains a profusely and handsomely illustrated paper, by Mr. Alex. Jay Wurts, on Discriminating Lightning Arresters and Recent Progress in Means for Protection against Lightning, and a short paper, by Prof. Anthony, on the Subdivision and Distribution of Artificial Sources of Illumination.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XIII. JULY, 1894. No. 7.

THE HYDRO-GEOLOGY OF THE UPPER MISSISSIPPI VALLEY AND OF SOME OF THE ADJOINING TERRITORY.*

BY DANIEL W. MEAD, MEMBER OF THE WESTERN SOCIETY OF ENGINEERS.

[Read April 6, 1893.†]

THE Upper Mississippi Valley, or that part of the Mississippi watershed above its confluence with the Missouri River, comprises an area of about 169,000 square miles.

The Western Lake Michigan watershed comprises only about 14,824 square miles of territory. This entire area, together with much adjoining territory, consisting of the Lake Michigan and Lake Superior basins and the valley of the Red River of the North, had a common geological origin and history, and, at a comparatively recent geological period, a common drainage system, all pouring their waters through

* The geological information contained in this paper was derived from sources too numerous to mention in detail. The Geological Reports of Wisconsin, Minnesota, Iowa and Illinois have been consulted, as have also Reports of the U. S. Geological Survey. The general idea of the hpyothetical maps of various geological ages was adapted from the maps of Prof. T. C. Chamberlain, contained in the Geological Survey of Wisconsin, Vol. I, on which, to a certain extent, the maps herein contained are based.

The thanks of the writer are also due to Prof. Chamberlain for information kindly furnished concerning the discharge of the waters of Lake Superior during the recession of the glaciers.

† Manuscript received March 19, 1894.—*Secretary.*

the Mississippi River into the Gulf of Mexico until subsequent geological changes so modified the topography as to produce the present drainage systems, a portion of which is here considered.

This territory comprises the greater portion of Illinois, Iowa, Wisconsin and Minnesota, and a small portion of northeastern Missouri and northwestern Indiana. It embraces within its area the richest farming country of the United States, a country largely settled and abounding in rapidly growing communities. In its northern part are forests of pine and rich mines of iron and copper, while in its southern part are valuable beds of fire clays and bituminous coal. Valuable deposits of stone and clay are found throughout its extent. It contains all that goes to make up the resources necessary for a rich and populous manufacturing and agricultural country.

In its water supplies for domestic, agricultural and mechanical use, on which its prosperity so largely depends, it is also richly endowed, and it is to a general review of these last-named resources that attention is here invited.

RAINFALL.

The rainfall of this region varies from an average of 26.44 inches at Fort Snelling, Minn., to 38.80 inches at Muscatine, Iowa. The average monthly rainfall at different points within this area is shown in Table I. This table gives only the average rainfall per month for the time during which observations have been taken, and does not show the variations from year to year. That these yearly variations are of considerable extent is shown by Table II, which gives the monthly rainfall at Chicago for each year from 1871 to 1891. The total yearly rainfall at Chicago has varied in the period here given from 26.54 inches in 1891 to 45.86 in 1883, and the average fall for the twenty years was 35.55 inches. The monthly variations, as shown in the table, are in proportion much greater than the yearly variations. For example, the rainfall in Chicago in July, 1874, was 0.58 inches, while in July, 1875, it was 7.18 inches.

TABLE I.

Average Rainfall at Localities in the Upper Mississippi and West Lake Michigan Valleys.

	No. of years record.	Elevation above sea level.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
		Feet.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.
Chicago, Ill.	18	715	2.20	2.35	2.55	3.19	3.35	3.86	3.55	3.18	3.09	3.46	2.66	2.35	35.79
Peoria, Ill.	18	475	1.66	2.09	2.38	3.08	3.54	4.44	3.59	2.91	3.59	3.20	2.25	2.21	34.95
Rockford, Ill.	15	800	2.41	2.13	2.42	2.89	3.12	4.17	3.72	3.36	2.78	3.38	2.16	2.10	34.64
Beloit, Wis.	18	750	2.04	2.04	2.60	2.57	3.00	4.36	3.59	3.94	3.50	2.91	1.92	2.07	34.54
Milwaukee, Wis.	18	697	2.28	1.92	2.74	2.68	3.15	3.86	3.18	3.04	3.10	2.69	2.00	2.04	32.68
Ft. Snelling, Minn.	18	820	0.82	0.71	1.22	2.22	3.39	4.31	2.95	3.16	3.38	1.63	1.56	1.09	26.44
Minneapolis, Minn.	18	856	1.18	1.07	1.56	2.37	3.49	4.09	2.84	3.51	3.42	2.04	1.34	1.79	28.70
St. Paul, Minn.	18	831	1.09	0.96	1.49	2.24	3.35	4.52	3.28	3.92	3.43	2.02	1.33	1.27	28.90
La Crosse, Wis.	15	744	1.34	1.29	1.79	2.08	3.31	4.11	4.75	3.94	4.44	2.30	1.77	1.28	32.40
Cresco, Ia.	16	1320	1.35	1.08	1.91	2.00	3.15	4.47	4.23	3.31	4.28	2.42	1.53	1.31	31.04
Davenport, Ia.	18	615	1.98	1.97	2.28	2.78	3.78	4.37	3.45	4.06	3.45	3.11	1.88	1.65	34.76
Dubuque, Ia.	17	665	1.64	1.50	2.40	2.58	3.83	4.48	4.45	3.93	4.68	2.85	1.99	1.89	36.22
Ft. Madison, Ia.	18	600	1.96	1.50	2.46	2.51	3.90	4.60	3.17	3.70	3.50	3.17	1.56	1.97	34.00
Independence, Ia.	18	850	1.32	0.99	1.68	2.17	4.08	5.19	5.30	4.31	5.43	2.50	1.56	1.40	35.93
Keokuk, Ia.	16	618	1.90	1.85	2.30	2.83	3.86	5.07	3.97	3.35	3.68	3.47	1.88	2.12	36.28
Monticello, Ia.	18	880	1.74	1.84	2.72	2.34	3.79	4.46	4.51	4.13	4.55	2.93	2.12	2.12	37.25
Muscatine, Ia.	18	582	2.29	2.00	2.65	2.88	4.49	4.90	4.02	3.83	3.98	3.35	2.13	2.28	38.80
St. Louis, Mo.	18	571	2.14	2.80	2.90	3.41	3.97	4.77	3.72	2.62	3.41	2.84	2.78	2.50	37.86
Ottawa, Ill.	10	500	2.35	2.47	2.72	3.34	3.83	3.54	4.30	3.41	3.36	2.78	2.54	2.55	37.19
Galesburg, Ill.	6	795	2.12	1.68	2.66	3.91	2.34	3.66	4.11	3.46	4.84	2.84	1.12	2.30	35.04
Appleton, Wis.	5	800	0.75	1.26	1.54	2.81	3.11	4.04	3.75	2.45	2.84	2.49	2.10	3.92	31.06
Ashland, or Bay City	4	610	2.24	1.47	2.48	4.93	6.09	4.61	3.72	5.62	5.88	4.87	3.18	1.36	46.45
Kenosha, Wis.	4	600	2.29	1.44	2.54	3.49	4.48	3.20	3.26	2.06	5.47	1.80	2.29	1.15	33.47
Manitowoc, Wis.	4	658	2.02	1.80	1.84	2.49	1.89	3.12	3.97	4.00	2.52	2.83	2.07	1.74	30.29
Ft. Ripley, Minn.	17	1130	0.71	0.63	1.34	1.61	2.91	4.18	3.98	2.74	3.46	1.43	1.42	0.70	25.11
Ft. Ridgely, Minn.	13	1230	1.61	1.29	1.72	1.88	3.01	2.57	2.64	3.90	3.17	1.49	1.20	1.21	25.69

TABLE II.

PRECIPITATION AT CHICAGO, ILL., FOR EACH MONTH AND EACH YEAR, FROM JANUARY, 1871, TO DECEMBER, 1891, INCLUSIVE.

(From a report of the Department of Public Works, Chicago, Ill.)

YEAR.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1871 .	4.13	1.45	2.66	3.70	3.90	5.56	2.52	2.01	0.74	....	3.62	3.44	....
1872 .	0.68	0.84	3.79	3.03	3.24	3.45	3.09	2.59	6.43	0.65	1.06	0.22	29.07
1873 .	2.56	0.47	0.89	6.22	7.20	1.44	4.04	1.58	3.53	2.43	1.61	4.44	36.41
1874 .	3.47	1.51	2.15	2.67	2.08	3.25	0.58	3.15	3.76	2.55	2.83	0.63	28.63
1875 .	0.96	1.99	1.43	2.32	3.64	5.17	7.18	3.29	4.39	4.32	0.75	2.62	38.06
1876 .	3.22	3.90	4.04	2.07	1.85	5.96	3.11	3.66	3.74	1.20	3.25	0.48	36.48
1877 .	1.91	0.06	5.37	2.42	1.81	6.04	2.98	3.06	2.02	6.51	6.08	2.75	41.01
1878 .	1.31	2.12	4.39	5.57	5.22	3.02	6.09	3.66	1.99	5.17	0.83	2.58	41.95
1879 .	0.54	1.47	2.37	1.93	3.89	3.18	5.58	0.45	1.18	2.72	4.93	2.47	30.71
1880 .	3.53	2.91	2.25	5.20	4.97	3.50	3.07	4.47	2.25	3.19	0.87	1.11	37.32
1881 .	0.87	5.98	2.99	1.84	1.85	5.93	4.31	0.54	4.34	6.89	5.97	2.67	44.18
1882 .	1.55	2.24	3.43	6.72	5.52	5.71	3.43	4.96	0.91	3.40	1.48	1.99	41.34
1883 .	1.74	4.74	0.42	3.72	7.32	5.61	5.53	1.21	1.36	7.36	5.26	1.59	45.86
1884 .	1.39	3.27	5.16	3.05	1.53	2.11	3.71	2.50	2.29	3.59	1.80	4.21	34.61
1885	3.18	2.01	0.57	4.00	3.17	5.20	2.44	11.28	2.97	3.87	2.33	3.35	44.37
1886 .	3.56	1.51	1.79	1.29	1.00	0.94	1.53	3.38	6.93	1.42	1.66	1.76	26.77
1887 .	3.13	5.10	0.89	0.46	1.38	1.63	1.05	3.35	4.03	2.03	2.41	3.67	29.13
1888 .	1.56	1.51	2.99	2.13	6.22	1.66	3.93	2.10	0.98	2.95	2.89	1.94	30.86
1889 .	1.64	1.31	1.43	2.35	5.38	2.93	9.56	0.39	2.75	1.82	3.49	1.90	34.95
1890 .	2.98	2.42	2.10	3.23	5.13	3.25	2.57	2.58	1.39	4.20	1.59	1.25	32.69
1891 .	1.99	1.95	2.13	3.14	2.09	2.42	2.47	4.52	0.32	0.36	3.83	1.32	26.54
Sums .	45.90	48.76	53.24	67.06	78.39	77.96	78.77	64.73	58.30	*66.63	58.54	46.39	*710.94
Means.	2.19	2.32	2.54	3.19	3.73	3.71	3.75	3.08	2.78	*3.33	2.79	2.21	*35.55

* For 20 years only. The other figures cover 21 years.

ULTIMATE DISPOSAL OF RAINFALL.

The ultimate disposal of the rainfall is modified by climate, temperature, vegetation and geological conditions; and these differ, not only for each locality, but, in each locality, with the season and with the previous relative humidity.

Of the total rainfall on the area here considered, portions are lost by

(*a*) Evaporation.

(*b*) Absorption by vegetation, utilization in plant growth and transpiration from plant surfaces.

(*c*) Flowage in streams.

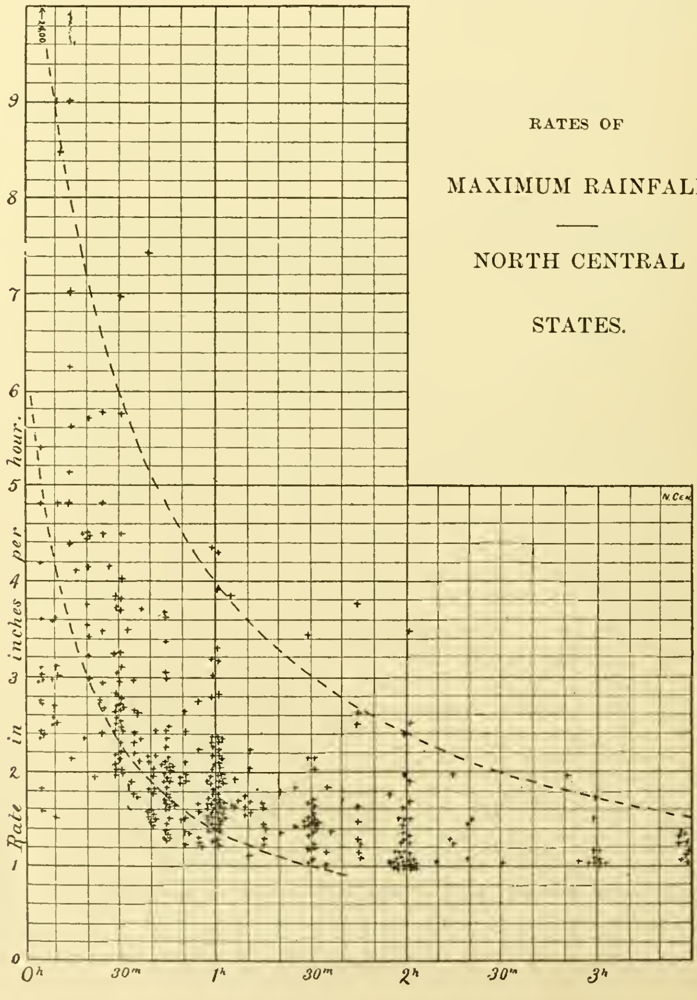
(*d*) Percolation into the soil and the underlying strata, furnishing

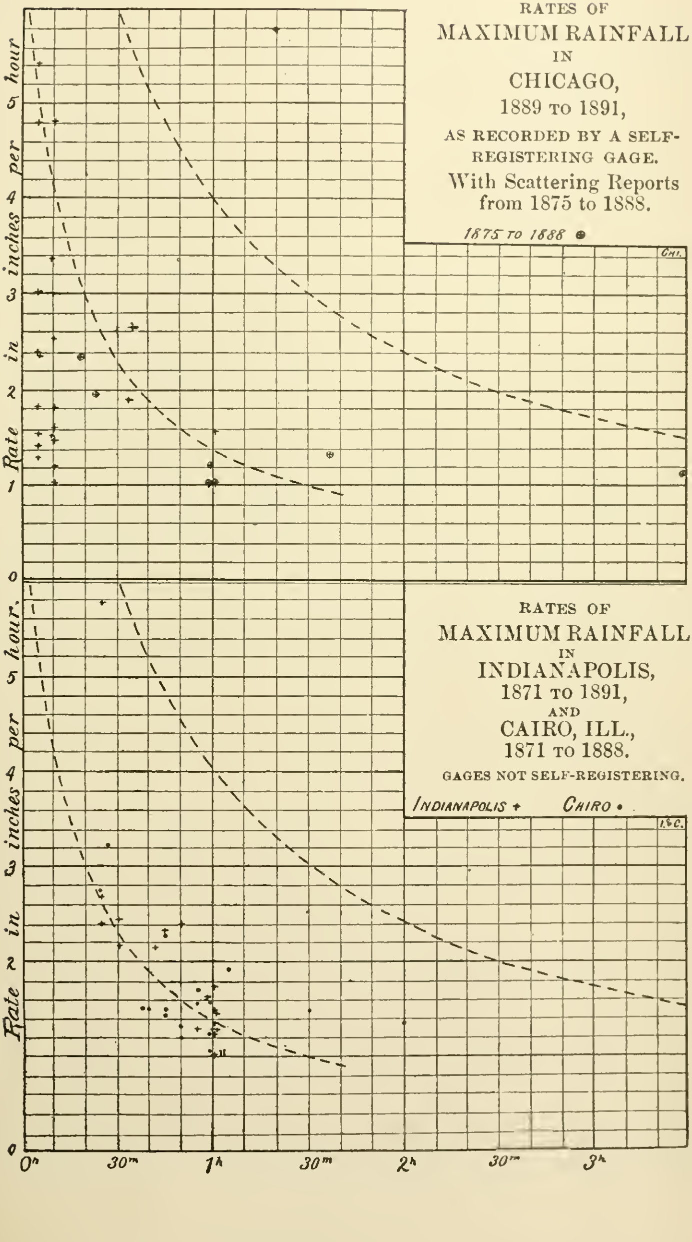
- (1) The dry-weather flow of streams.
- (2) A reserve from which plant life draws its necessary supply during the rainless period.
- (3) Waters which saturate and flow in underlying geological strata.

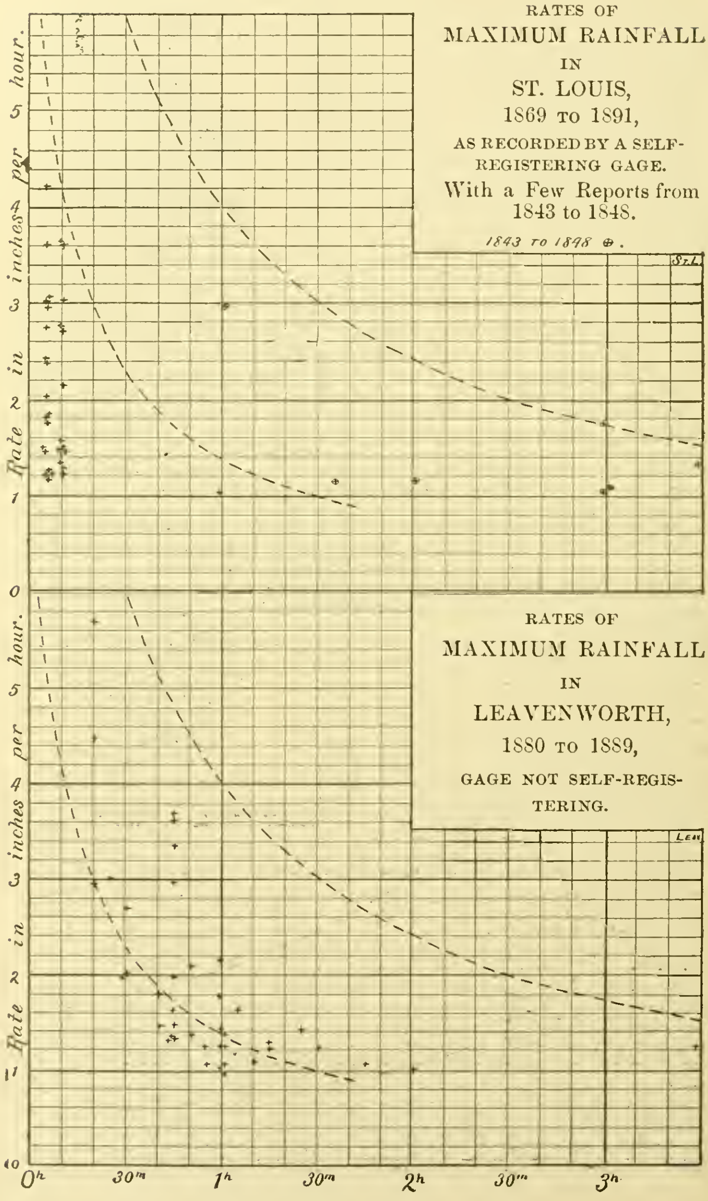
The yearly distribution of the rainfall has much to do with its ultimate distribution. Where the rainfall is evenly distributed throughout the year, a larger proportion is absorbed by vegetation, imbibed by soil and rocks and evaporated, and a smaller proportion flows away in streams. Where the rainfall is concentrated in short periods, a larger percentage flows away in streams as flood waters and a less proportion is appropriated in the other ways. The variation in the amount which may be assimilated by vegetation or evaporated during a short period is limited. So, to a less degree, is the inhibition of soils and rocks; for these strata, if once saturated, force the water to flow away as flood waters. A fall of an inch or more per hour upon frozen ground destitute of vegetation may produce a considerable flood, whilst the same fall, distributed over twenty-four hours, with vegetation at its best and with low ground water, may be scarcely noticeable in its effect upon the flow of streams. The maximum rates of rainfall in this region are very clearly shown in the diagrams kindly furnished by Prof. A. N. Talbott. These show (1) the rates of maximum rainfall in the North Central States (compiled from data from Ohio, Indiana, Illinois, Missouri, Kansas and Iowa); (2) the rate of maximum rainfall at Chicago and Cairo, Ill., and at Indianapolis, Ind.; and (3) the rate of maximum rainfall at St. Louis, Mo., and at Leavenworth, Kan. The curves are platted from formulæ determined by Prof. Talbott from a study of the diagrams. The upper is called the curve of rare rainfall, and its equation is $Y = \frac{6}{5\,x}$. The lower is called the curve of ordi-

nary maximum, and its equation is $Y = \frac{1.75}{0.25\,x}$. In each equation Y is the rate of rainfall, in inches per hour, for the time x expressed in hours. The points on the diagram represent the actual record of individual storms.

Other climatic factors influence to a considerable extent the ultimate disposal of the rainfall. The temperature and the direction and velocity of the wind very largely modify evaporation, and by retarding or stimulating vegetation, they also diminish or increase the amount of water disposed of by this means. The elevation and inclination of




RATES OF
MAXIMUM RAINFALL
IN
CHICAGO,
1889 TO 1891,
AS RECORDED BY A SELF-REGISTERING GAGE.
With Scattering Reports from 1875 to 1888.
1875 TO 1888
CHI.
RATES OF
MAXIMUM RAINFALL
IN
INDIANAPOLIS,
1871 TO 1891,
AND
CAIRO, ILL.,
1871 TO 1888.
GAGES NOT SELF-REGISTERING.
INDIANAPOLIS +
CAIRO •
I.&C.
Rate in inches per hour
Rate in inches per hour
0
1
2
3
4
5
0h
30m
1h
30m
2h
30m
3h


RATES OF
MAXIMUM RAINFALL
IN
ST. LOUIS,
1869 TO 1891,
AS RECORDED BY A SELF-REGISTERING GAGE.
With a Few Reports from 1843 to 1848.
1843 TO 1848 ⊕.
St. L.
RATES OF
MAXIMUM RAINFALL
IN
LEAVENWORTH,
1880 TO 1889,
GAGE NOT SELF-REGISTERING.
Len.
Rate in inches per hour.
Rate in inches per hour.
0ʰ
30ᵐ
1ʰ
30ᵐ
2ʰ
30ᵐ
3ʰ

the surface also exert a marked influence. The elevation modifies the temperature, and consequently the evaporation. The inclination of the surface, by facilitating rapid drainage, increases the percentage which flows away in streams and decreases the amount evaporated, absorbed by vegetation or imbibed by the strata. In view of these various modifying influences, which vary relatively from month to month and from year to year, it will be seen that all conclusions as to the amounts disposed of in the various ways mentioned must be very approximate.

It is not, however, the purpose of this paper to discuss at length the ultimate proportional disposition of the rainfall in this territory, but simply to point out the destinations reached by it, to call attention to certain facts respecting the principles which modify the comparative amounts commonly credited to each, and to discuss the principles and conditions which modify the amount and disposition of those portions of the rainfall which are absorbed by the strata or which flow away on their surfaces.

(*a*) EVAPORATION.

Evaporation, as has been pointed out, varies greatly with the temperature, with the direction and velocity of the wind, with the relative humidity of the atmosphere and with the local topography. Its amount, like that of the local rainfall, while in a general way approximately constant, varies with circumstances in different months and in different years. Comparatively few experiments have as yet been made to determine rates of evaporation, and most of these have referred to evaporation from water surfaces. Experiments show, however, that the daily evaporation from soil varies with its physical condition. Evaporation from a wet surface takes place much more rapidly than from water, but gradually diminishes as the ground dries, until it becomes practically nothing, even though the ground water be high enough to maintain vegetation. Careful and continued experiments, however, must be made, in order to obtain a satisfactory collection of valuable data concerning evaporation from land and plant surface.

Owing to the shortness of the time during which the water remains on the surface where it is subjected to evaporation, the amount of evaporation from water surfaces is greatly in excess of the average of that which takes place on the land surface in the same territory. For, as a rule, except in swampy and poorly drained ground, the water runs immediately into the adjacent water courses or sinks into the ground; only a very small percentage of the rainfall being directly evaporated from the land surface. Most of the evaporation takes place by plant transpiration and from exposed surfaces of water.

The total amount evaporated, therefore, varies largely not only with

climatic influences, but with the topography and geology of the district. These, according to circumstances, may either permit or prevent the formation of lakes and swamps, the rapid percolation of water into the soil and underlying strata, or its rapid removal by streams.

The presence or absence of forests has also, as shown by a series of observations in Germany, a marked effect on evaporation. Prof. M. W. Harrington (see Bulletin No. 7, U. S. Dept. of Agriculture, p. 97) has compiled the accompanying diagram showing the effect of forests upon the monthly evaporation. The upper curve represents the evaporation from water surfaces in the open country, while the lower curve shows the evaporation from water surfaces in the woods. The shaded area thus illustrates the saving due to the cover and protection of forests.

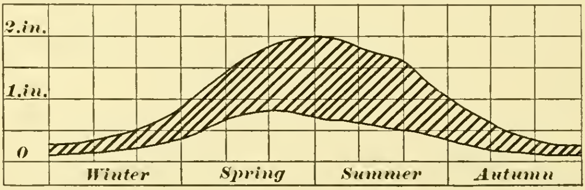


Figure showing, in the shaded portion, the effect of forests in diminishing evaporation.

Few experiments have been made in the area here considered. It has been estimated that Lake Michigan loses annually 22 inches by evaporation, but the average for the entire Upper Mississippi Valley will probably not exceed 10 inches annually. Some available data concerning the evaporation of water under various circumstances and in various places are given in Table III.

Locality.	MONTHLY EVAPORATION IN INCHES.												Years of observation.	ANNUAL. Evaporation.			ANNUAL. Rainfall.			Evaporation from surface of	Authority.
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.		Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.		
Fort Collins, Col. . .	.97	1.69	3.11	3.78	4.02	5.02	5.32	5.45	4.44	3.00	.97	1.26	2	39.03	40.24	37.83				Water.	Ft. Collins Exp. Sta.
Fort Apache, Arizona	3.4	3.9	5.0	7.80	8.8	10.9	9.4	8.5	6.8	6.5	5.1	3.5	1	79.6	101.2	56.0				Water.	Report on irrigation and water storage in arid regions.
Sacramento, Cal. . .	1.8	3.1	3.7	4.30	4.2	5.6	5.9	5.6	6.5	7.3	3.9	2.4	1	54.3						Water.	
Los Angeles, Cal. . .	2.3	2.0	2.8	3.40	3.0	3.8	3.2	3.5	3.1	4.1	3.0	3.0	1	57.2						Water.	
Boston, Mass.	.90	1.20	1.8	3.10	4.61	5.86	6.28	5.49	4.09	2.95	1.63	1.2	9	39.11						Water.	Desmond Fitz Gerald, C. E.
Endrup, Denmark . .	.7	.5	.9	2.0	3.7	5.4	5.2	4.4	2.6	1.3	.7	.5	11	27.9	30.06	24.0				Water.	Nathaniel Beardsmore.
Endrup, Denmark . .	.7	.8	1.2	2.6	4.1	5.5	5.2	4.7	2.8	1.3	.7	.5	8	30.1	32.6	25.7				Short grass.	Nathaniel Beardsmore.
Endrup, Denmark . .	.9	.6	1.4	2.6	4.7	6.7	9.3	7.9	5.2	2.9	1.3	.5	8	41.0	65.9	29.2				Long grass.	Nathaniel Beardsmore.
Bolton-le-Moore, Eng.	.64	.95	1.59	2.59	4.38	3.84	4.02	3.06	2.02	1.25	.81	.47	10	25.65	35.95	22.02				Earth.	Nathaniel Beardsmore.
Whitehaven, Eng. .	.95	1.01	1.77	2.71	4.11	4.25	4.13	3.29	2.96	1.76	1.25	1.03	9	29.21			4.35			Earth.	J. T. Fanning, C. E.
Ferrybridge, Eng. . .	2.07	2.59	2.56	1.91	4.52	4.88	4.44	3.08	2.99	2.23	1.63	1.79		34.69			25.24			Water exposed to sun and wind.	G. D. Dempsey, C. E.
Ferrybridge, Eng. . .	1.58	1.69	1.55	1.27	3.02	3.25	2.96	2.05	1.99	1.49	1.09	1.10		23.04			25.21			Water shaded but exposed to wind.	G. D. Dempsey, C. E.
Ferrybridge, Eng. . .	1.22	.44	.86	2.98	.73	1.58	2.74	2.46	1.00	2.40	.88	1.09		18.38			25.24			Soil drained.	G. D. Dempsey.
Ferrybridge, Eng. . .	1.94	2.09	2.16	1.49	3.89	4.73	4.39	3.28	3.14	2.76	1.74	1.67		33.28			25.24			Soil saturated.	G. D. Dempsey, C. E.
Cambridge, Mass. . .														56							J. T. Fanning, C. E.
Salem, Mass.														56							J. T. Fanning, C. E.
Syracuse, N. Y. . . .														50.2							J. T. Fanning, C. E.
Ogdensburg, N. Y. . .														49.37							J. T. Fanning, C. E.
Croton River, N. Y. .														24.15							J. T. Fanning, C. E.
N. Y. rec'g Reservoir													6	39.21							J. T. Fanning, C. E.
Lee Bridge, Eng. . .													13	22.2	26.93	17.33	27.7			Water.	J. T. Fanning, C. E.
Lee Bridge, Eng. . .													13	19.55	25.14	12.07	27.7			Soil.	J. T. Fanning, C. E.
Lee Bridge, Eng. . .													13	4.65	9.10	1.43	27.7			Sand.	J. T. Fanning, C. E.
	MONTHLY RAINFALL IN INCHES.																				
Fort Collins, Col. .	.68	.56	.65	1.89	2. 1	1.54	1.72	1.27	.78	1.15	.35	.28	10				13.58	14.48	9.10		Ft. Collins Exp. Sta.
Fort Apache, Arizona	1.34	1.80	1.65	.84	.47	.72	4.04	4.29	1.54	1.34	1.17	1.93	15				21.04	29.47	14.77		Report on irrigation and water storage in arid regions.
Sacramento, Cal. . . .	3.78	2.80	2.73	1.85	.74	.12	.02	.00	.12	.79	2.14	4.71	42				19.80	34.92	8.20		
Los Angeles, Cal. . .	4.08	3.74	2.27	1.29	.31	.09	.02	.10	.04	.82	1.71	3.84	19				18.31	40.39	5.53		
Boston, Mass.	3.98	3.78	4.36	4.06	3.79	3.27	3.71	4.39	3.55	3.84	4.31	3.96	73				42.00				Desmond Fitz Gerald, C. E.
Endrup, Denmark . .	1.5	1.7	1.0	1.6	1.5	2.2	2.40	2.4	2.0	2.3	1.8	1.5	12				21.9	28.8	14.6		Nathaniel Beardsmore.
Bolton-le-Moore, Eng.	4.63	4.03	2.25	2.22	2.23	4.07	4.32	4.77	3.79	5.07	46.4	3.94	10				45.96	55.19	34.63		Nathaniel Beardsmore.

(*b*) ABSORPTION BY VEGETATION.

In the Report of the Kansas State Board of Agriculture for December 31, 1889, Mr. W. Tweeddale, C.E., gives the following table (Table IV), containing the results of investigations by M. E. Risler, a Swiss observer, upon the daily consumption of water by different kinds of crops.

TABLE IV.

Daily Consumption of Water by Crops.

Crop.	Inches of Water. Minimum.	Maximum.
Lucern grass	0.134	0.267
Meadow grass	0.122	0.287
Oats	0.140	0.193
Indian corn	0.110	1.570
Clover	0.140	. .
Vineyard	0.035	0.031
Wheat	0.106	0.110
Rye	0.091	. .
Potatoes	0.038	0.055
Oak trees	0.030	0.038
Fir trees	0.020	0.043

Mr. Tweeddale finds that this table agrees with careful experiments made in France and elsewhere, and calculates from it that from seed time to harvest cereals will take up 15 inches of water and grass may absorb as much as 37 inches. These figures agree closely with practice in irrigation.

This table shows also one of the important reasons why a decrease of stream flow follows the destruction of forests and their replacement by meadows and cultivated fields. It is quite evident also that if the watersheds were covered by grasses or cereals there would be comparatively little water left for the flow of streams. From this it will be seen that the character of the vegetation on a watershed exerts a considerable influence on the ultimate distribution of the rainfall.

The following table (Table V) gives the result of experiments by Mr. F. A. King at the Wisconsin Agricultural Experiment Station, to determine the amount of water required to produce a pound of dry matter in Wisconsin (see Eighth Annual Report Wisconsin Agricultural Experiment Station, p. 126), including transpiration and evaporation from the cultivated surface.

TABLE V.

THE AMOUNT OF WATER REQUIRED TO PRODUCE A POUND OF DRY MATTER IN WISCONSIN FOR OATS, BARLEY AND CORN.

		Lbs. of water used.	Lbs. of dry matter produced.	Lbs. of water per lb. of dry matter.		Computed yield per acre.	Computed amount of water.	
					Mean.	Lbs.	In tons per acre.	In inches.
Barley .	1	158.3	.3966	399.14	401.74			
Barley .	2	141.03	.3488	404.33		7,441	1,494.67	13.19
Oats . .	1	224.25	.4405	509.31	501.47			
Oats . .	2	220.7	.4471	493.63		8,861	2,221.76	19.60
Corn . .	1	300.45	1.0152	295.95	301.49			
Corn . .	2	298.65	.9727	307.03		19,845	2,991.53	26.39

(c) FLOWAGE OF STREAMS.

The proportion of the rainfall lost through the flow of streams is capable of more accurate determination than are the portions lost in other ways; for the stream flow is visible and tangible, and may be accurately measured at any particular time or during any period.

Many of the streams of this area have been accurately gaged for purposes of navigation, of power or of water supply, and many of the results of these gagings are available. The various factors which modify the flow of streams have already been mentioned, and, as no two streams are exactly alike in their climatic, topographic and geologic condition, we find also that they differ in the proportion of the rainfall which they carry off; the capacity of each stream depending upon its own conditions. Mr. J. L. Greenleaf, C.E., in the Tenth U. S. Census Report, Vol. XVII, offers a general estimate of the ratio of the average flow of streams to the average rainfall on their watersheds. This estimate is embodied in Table VI. Although the table gives a fairly accurate general idea of the discharge of the streams in this area, it is impossible to tabulate all the conditions which arise and which may materially modify the relative disposal of the rainfall. Hence, in considering any subdivision of this area, local data must be collected, and local geological and topographical features must be studied in the light of the known facts respecting the area taken as a whole.

TABLE VI.

Table of Ratio of Average Flow to Average Precipitation in the Upper Mississippi Valley.

Character of region drained.	Average temperature. Three summer months.	Average temperature. Three winter months.	Ratio of average yearly flow to average annual rainfall.
	Deg. Fahr.	Deg. Fahr.	
1. Rather level woodland, with many lakes and wooded swamps	60 to 64	4 to 12	35 to 40
2. Sandy ridges, rolling woodland and prairie, few swamps and lakes, largely clay soil	64 to 68	8 to 16	30 to 40
3. Rolling woodland and prairie, largely uncultivated, few swamps, no lakes, largely clay soil	64 to 68	8 to 16	27 to 35
4. Flat to rolling prairie, partly cultivated, scattered woodland, largely clay soil	60 to 70	12 to 20	20 to 30
5. Flat to rolling prairie, largely uncultivated	68 to 72	16 to 26	15 to 20
6. Extreme cases of last division . .	68 to 72	16 to 26	10 or less (?)

From the same source are taken most of the data included in Table VII, which gives the drainage area, the rainfall and the flow at various points on the Upper Mississippi River, and in Table VIII, which gives the length, the drainage area, the rainfall, the low water and high water discharge and the rate of discharge of the various rivers in this area.

From Table VIII it will be seen that there is quite a wide variation in the ratio of flow of some of the streams of this district, a variation due of course to differences in the proportion of the rainfall lost by evaporation, by absorption or by imbibition.

The disposition of that portion of the rainfall which is not evaporated or absorbed by vegetation, depends entirely on geological conditions. Rain falling on impervious rocks with highly inclined surfaces runs rapidly off in creeks and rivers, but that which falls on sandstones or on deposits of sand sinks at once into the strata, forming a subterranean flow generally in the direction of the inclination of the strata, and, after the strata become saturated, appears in the depressions as surface waters. In Archean regions the impervious rocks give rise to conditions unfavorable to subterranean flow. In the arid regions of the West, the surface strata are often so pervious that the river systems amount to but little, being only torrential in their character, while the subterranean waters are by far the most important. In the region here considered, with the exception of a limited area in the extreme northern portion, consisting of Archean rocks, the surface and subsurface waters are more nearly equal in amount, both assuming considerable importance.

TABLE VII.—DRAINAGE AREA, RAINFALL AND DISCHARGE ABOVE DIFFERENT STATIONS ON THE UPPER MISSISSIPPI RIVER.

STATION.	Distance below source of the river.	Elevation of ordinary low water above the sea level.	Fall from preceding station.	Average slope per mile to source of river.	Drainage area above station.	Average annual precipitation above station.	Average annual precipitation per second on area above station.	Flow per second past station. Ordinary low flow.	Flow per second past station. Average flow.	Flow per sec. past station per sq. mile of drainage area. Ordinary low flow.	Flow per sec. past station per sq. mile of drainage area. Average flow.	Ratio of average precipitation above station.	Ratio of ordinary low flow to average flow.
	Miles.	Feet.	Feet.	Feet.	Sq miles.	In.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Per cent.	
Utmost source of the Mississippi	.	1,680.00	. . .	. . .	. . .	. . .	. . . .	. . . .	. . . .				. . .
Mouth of Pinniddiwin River	34.00	1,375.00	305.00	8.941	384	25.00	707	127	275	0.33	0.716	38.8	0.462
Mouth of east branch of the Mississippi	53.00	1,356.00	19.00	6.113	513	25.00	1,000	180	389	0.331	0.716	38.9	0.463
Mouth of Turtle River and outlet of Cass Lake	82.5	1,299.46	56.54	4.615	1,073	25.00	1,979	361	783	0.336	0.729	39.5	0.468
Mouth of Leech Lake River	139.00	1,278.56	20.90	2.888	2,554	25.00	4,707	896	1,903	0.351	0.746	40.4	0.471
Head of Grand Rapids	189.1	1,249.06	29.50	2.273	2,966	....	5,466	1,036	2,192	0.349	0.739	40.1	0.473
Foot of Frand Rapids	189.4	1,244.06	5.00	2.249	2,966	....	5,466	1,036	2,192	0.349	0.739	40.1	0.473
Mouth of Prairie River	191.9	1,242.96	9.87	2.103	3,554	25.00	6,370	1,183	2,572	0.342	0.744	40.3	0.460
Mouth of Swan River	230.9	1,225.85	8.34	1.534	3,928	25.06	7,257	1,330	2,935	0.338	0.747	40.4	0.453
Mouths of the Willow and White Elk Rivers	301.9	1,198.20	27.65	1.596	5,049	25.16	9,364	1,672	3,787	0.331	0.750	40.4	0.442
Mouth of Pine River	355.9	1,171.31	26.89	1.120	6,705	25.21	12,456	2,167	4,953	0.323	0.739	39.7	0.438
Mouth of Crow Wing River	387.9	1,145.06	26.25	1.121	10,573	25.30	19,723	3,328	7,602	0.315	0.719	38.5	0.438
Head of Sauk Rapids and mouth of Sauk River	439.9	987.66	157.40	1.347	13,242	25.45	24,834	4,123	9,174	0.312	0.693	36.9	0.419
Mouth of Elk River	484.1	850.26	137.40	1.716	14,360	25.49	26,974	4,462	9,816	0.311	0.684	36.3	0.456
Mouth of Crow River	489.1	841.06	9.20	1.715	17,457	26.02	33,577	5,391	11,924	0.309	0.683	35.5	0.452
Mouth of Rum River	497.3	825.96	15.10	1.717	19,016	26.18	36,682	5,859	12,855	0.308	0.676	35.3	0.456
Minneapolis, at St. Anthony's Falls	514.6	793.36	32.60	1.723	19,585	....	37,933	6,017	13,193	0.307	0.674	34.7	0.457
Mouth of Minnesota River	523.6	683.52	109.84	1.521	35,819	27.07	71,456	8,576	20,922	0.239	0.584	29.2	0.410
St. Paul Bridge	527.6	681.36	2.16	1.893	35,824	....	71,467	8,577	20,925	0.239	0.584	29.2	0.410
Mouth of St. Croix River	556.6	666.49	14.87	1.821	43,872	27.63	89,324	11,500	27,398	0.262	0.624	30.6	0.420
Mouth of Chippewa River	610.85	659.56	6.93	1.670	55,876	28.10	118,687	15,719	37,712	0.281	0.674	31.7	0.417
Mouth of Trempealeau River	658.1	633.29	26.27	1.590	59,256	28.99	126,571	16,648	39,766	0.276	0.671	31.4	0.419
Mouth of Black River	682.6	624.77	8.52	1.547	61,659	29.18	132,590	17,433	41,840	0.283	0.679	31.5	0.417
Mouth of Upper Iowa River	716.1	611.51	13.26	1.492	65,484	29.38	141,737	18,705	44,186	0.286	0.675	31.1	0.423
Mouth of Wisconsin River	757.62	600.11	11.40	1.425	78,565	30.31	175,465	23,704	56,101	0.314	0.742	31.9	0.423
Dubuque	812.11	581.48	18.63	1.353	81,822	....	182,281	24,455	57,845	0.301	0.711	31.6	0.423
Mouth of Maquoketa River	840.76	572.36	6.06	1.318	83,772	30.58	188,789	25,111	29,518	0.312	0.710	31.5	0.422
Fulton	873.71	563.00	9.36	1.278	84,857	....	191,746	25,393	60,228	0.299	0.710	31.4	0.422
Mouth of Wapsipinicon River	889.33	558.25	4.75	1.261	87,558	30.85	199,109	26,095	62,139	0.298	0.711	31.2	0.420
Head of Rock Island Rapids at Le Claire	896.46	557.43	0.82	1.252	87,703	....	199,504	26,130	62,224	0.298	0.710	31.1	0.420
Foot of Rock Island Rapids at Rock Island	911.21	537.03	20.40	1.254	87,842	....	199,883	26,163	62,321	0.298	0.709	31.1	0.420
Mouth of Rock River	913.33	536.37	0.66	1.252	98,821	31.39	228,596	30,001	72,269	0.304	0.731	31.6	0.416
Muscatine	943.22	526.86	9.51	1.223	89,100	....	229,356	30,125	72,436	0.304	0.731	31.5	0.416
Mouth of Iowa River	963.72	521.22	5.64	1.202	111,845	32.27	265,933	33,303	81,199	0.291	0.726	30.5	0.411
Burlington	995.21	508.36	12.86	1.177	113,495	....	270,264	33,700	82,184	0.297	0.724	30.4	0.410
Head of Desmoines Rapids at Montrose	1,025.31	497.76	10.60	1.251	118,513	....	283,899	34,914	85,425	0.295	0.721	30.0	0.409
Foot of Des Moines Rapids at Keokuk	1,036.43	475.59	22.17	1.162	118,705	....	284,408	34,956	85,537	0.294	0.721	30.0	0.409
Mouth of Des Moines River	1,039.33	473.64	1.97	1.161	133,395	32.12	325,532	37,894	93,762	0.284	0.702	28.8	0.404
Hannibal	1,091.01	448.21	25.43	1.136	137,460	....	336,306	38,818	96,131	0.282	0.699	28.5	0.404
Mouth of Illinois River	1,180.33	404.70	43.51	1.080	172,229	33.93	430,542	42,096	118,446	0.265	0.688	27.5	0.355
Above mouth of Missouri River	1,204.33	392.70	12.00	1.069	172,525	....	431,349	42,161	118,624	0.265	0.688	27.5	0.355

TABLE VIII.

Length, Drainage, Area, Rainfall and Discharge of Principal Tributaries of the Upper Mississippi River.

Stream.	Distance of mouth from source of the Mississippi.	Length.	Average of basin.	Average annual precipitation on the basin, in rain and melted snow. Spring.	Summer.	Autumn.	Winter.	Year.	Average annual precipitation per second on the entire basin.	Discharge of river per second. Ordinary low flow.	Average flow.	Discharge per second per square mile of drainage area. Ordinary low flow.	Average flow.	Ratio of average discharge to average annual precipitation on the basin.
	Miles.	Miles.	Sq. m.	Inches.	Inches.	Inches.	Inches.	Inches.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	Cu. ft.	P. ct.
Mississippi above the Pinniddiwin river	. .	23	233	6,84	9.25	6.27	2,64	25.00	429	77	167	0.33	0.717	39
Pinnidiwin	33.8	17	151	-6.84	9,25	6.27	2.64	25.00	278	50	108	0.33	0.615	39
East branch of the Mississippi	52.5	26	133	6.34	9.25	6.27	2.64	25.00	245	44	96	0,33	0.722	39
Turtle	80.5	40	300	6.84	9,25	6.27	2.64	25.00	552	102	232	0,34	0.773	42
Leech Lake	139.0	50	1,105	6.84	9.25	6.27	2.64	25.00	2,035	409	856	0,37	0.775	42
Prairie	191.9	19	491	6.84	9,25	6,27	2.64	25.00	904	147	380	0.30	0.774	42
Swan	230.9	49	349	6.84	9.75	6,27	2.64	25.50	656	105	276	0.30	0.791	42
Sandy Lake	271.9	. .	421	6.84	9.75	6.27	2.64	25.50	791	131	332	0.31	0.789	42
Willow and White Elk rivers	301.3	. .	547	6.84	9.75	6.27	2.64	25.50	1,028	159	411	0.29	0.751	40
Rice	318.9	24	293	6.84	9.75	6.27	2.64	25.50	550	88	220	0.30	0.751	40
Pine	355.9	140	961	6,84	9.75	6.27	2.64	25.50	1,805	288	722	0.30	0.750	40
Crow Wing	387.9	105	3,560	6.84	9.75	6,27	2.64	25.50	6,688	1,068	2,475	0.30	0.695	37
Sauk	439.9	82	968	6.55	11.38	5.49	2.58	26.00	1,854	290	593	0.30	0.613	32
Elk	484.1	100	587	6.55	11.38	5,49	2.58	26.00	1,124	158	337	0.27	0.591	30
Crow	489.1	141	3,085	6,18	12.30	6.81	2.71	28.00	6,324	929	2,036	0.30	0.660	32
Rum	497.3	136	1,539	6.23	11.58	6.61	2.58	27.00	3,061	462	918	0,30	0.596	30
Minnesota	523.6	256	16,027	7.03	11.75	6.60	2,62	28.00	33,060	2,500	7,604	0.156	0.474	23
Saint Croix	556.8	168	7,576	7.81	12.14	7.09	2.96	30.00	16,744	2,796	6,195	0.37	0.818	37
Cannon	577.8	90	1,492	7.21	12.04	6.84	2.91	29.00	3,188	433	893	0.29	0.599	28
Chippewa	610.8	165	9,573	8.39	13.87	7.94	3.80	34.00	23,978	3,542	8,872	0.37	0.927	37
Zumbio	617.8	80	1,346	7.21	12.04	6.84	2.91	29.00	2,876	377	748	0.28	0.556	26
Buffalo	622.6	50	468	8.12	13.57	7.63	3.68	33.00	1,138	131	296	0.28	0.632	26
Trembealeau	658.1	73	723	8.12	13.57	7.63	3.68	33.00	1,768	202	456	0.28	0.631	26
Black	682.6	166	2,272	8.39	13.87	7.88	3.86	34.00	5,691	750	1,992	0.33	0.877	35
Root	686.6	95	1,669	6.08	11.60	8.22	4.10	30.00	3,556	467	926	0,28	0.576	26
Upper Iowa	716.1	110	952	7.21	11.03	8.66	4.10	31.00	2,174	451	565	0.28	0.593	26
Wisconsin	757.6	407	12,280	8.57	12.79	8.21	5.43	35.00	31,663	4,790	11,399	0,39	0.928	36
Turkey	779.3	115	1,725	7.41	11.53	8.76	4.30	32.00	4,067	483	1,057	0.28	0.613	26
Maquoketa	840.7	116	1,904	9.51	11.72	8.90	5.87	36.00	5,050	514	1,313	0.27	0.690	26
Wapsipinicon	889.3	205	2,644	9.82	13.23	8.90	5.05	37.00	7,207	687	1,874	0.26	0.709	26
Rock	913.3	386	10,973	9.68	11.55	8.99	5.28	35.50	28 697	3,900	9,944	0.36	0.906	35
Iowa	963.7	326	12,466	8.03	16.63	9.33	5.01	39.00	35,816	3,117	8,596	0.25	0.690	24
Henderson	988.8	54	612	8.53	12.98	8.09	5.40	35.00	1,578	147	379	0.24	0.619	24
Skunk	999.3	243	4,427	9.88	13.23	8.84	5.05	37.00	12,067	1,062	2,896	0.24	0.654	24
Des Moines	1039.3	402	14,690	9.88	14.31	9.60	4.21	38.00	41,124	2,938	8,225	0.20	0.560	20
Fox	1042.5	62	600	10.34	11.08	8.45	6.13	36.00	1,591	138	350	0.23	0.583	22
Wyaconda	1062.5	85	501	10.34	11.08	8.45	6.13	36.00	1,329	115	292	0.23	0.583	22
Fabius	1075.7	98	1,987	10.34	11.08	8.45	6.13	36.00	5,270	457	1,159	0.23	0.583	22
Salt	1117.6	185	3,044	9.34	10.58	8.10	5.98	34.00	7,625	669	1,678	0.22	0.551	22
Cuivre	1165.1	99	1,196	10.54	11.88	8.45	7.13	38.00	3,348	275	737	0.23	0.616	22
Illinois	1180.3	397	29,013	10.31	11.79	8.51	6.39	37.00	79,038	2,000	18,980	0.07	0.654	24

The surface slope of the country greatly affects the rapidity with which the rain waters are directly removed and the consequent amount of the flood waters. The dry weather flow is governed chiefly by the porosity of the strata and comparatively little by the surface slope, except that tracts of swamp land retain the flood waters.

The extreme variation in altitude in this area is from about 2,000 feet above sea level in northern Minnesota and 1,600 feet in northeastern Wisconsin, to 381 feet above sea level at the mouth of the Missouri River. Some data concerning the low water slope of the Uupper Mississippi, taken from Humphrey's and Abbot's Report on the Physics and Hydraulics of the Mississippi River, are given in Table IX.

TABLE IX.

LOW WATER SLOPE OF THE UPPER MISSISSIPPI.

Locality.	Distance above mouth of Missouri.	Elevation above sea.	Fall per mile.	Remarks.
	Miles.	Feet.	Feet.	
Utmost source . . .	1330	1680	.00	
Itasca Lake . .	1324	1575	17.50	
Entrance to Lac Travers	1234	1456	1.32	
Entrance to Lake Cass	1189	1402	1.20	10 inches in the lake.
Mouth of Leech Lake River	1109	1356	.57	35 inches in the lake.
Head of Falls of Peckagama . . .	1061	1340	.33	
Mouth of Swan River	998	1290	.73	Rapids intervening.
Mouth of Sandy Lake River	960	1254	.95	Rapids intervening.
Mouth of Pine River	863	1176	.79	Rapids intervening.
Mouth of Crow Wing River	815	1130	.95	Rapids intervening.
St. Paul	658	670	2.93	Sink rapids.
La Crosse	514	639	.32	Falls of St. Anthony etc.
Prairie du Chien . .	453	600	.64	
Head of Rock Island Rapids . .	316	502	.66	
Foot of Rock Island Rapids	295	483	1.47	Rapids intervening.
Mouth of Missouri River	6	381	.35	Des Moines Rapids intervening.

Lake Pepin 27 miles long, 2 to 3 miles wide.
Rock Island Rapids 13 miles long, fall 22 feet.
Des Moines Rapids 11 miles long, fall 21 feet.

Table X contains further data concerning the slope of many of the rivers in this area. It is derived largely from the report on Water Powers of the Tenth U. S. Census Reports.

TABLE X.

SLOPE OF SOME OF THE TRIBUTARIES OF THE UPPER MISSISSIPPI RIVER.

Streams.	Tributary to	From what State.	From	To	Distance, Miles.	Fall. Feet.	Slope per mile, Feet.
Milwaukee River	Lake Michigan.	Wisconsin.	Head waters.	Mouth.	66	500	7.58
Sheboygan River	Lake Michigan.	Wisconsin.	Head waters.	Mouth.	45	360	8.00
Manitowoc River. . . .	Lake Michigan.	Wisconsin.	Head waters.	Mouth.	42	350	8.33
Lower Fox River	Lake Michigan.	Wisconsin.	Lake Winnebago.	Mouth.	37½	165	4.40
Menominee River	Lake Michigan.	Wisconsin.	Head waters.	Mouth.	160	975	6.09
Maquoketa River	Mississippi River.	Iowa.	Manchester, Ia.	Mouth.	87	333	3.83
Wapsipinecon River . . .	Mississippi River.	Iowa.	Independence, Ia.	Mouth.	135	328	2.43
Iowa River	Mississippi River.	Iowa.	Near Iowa Falls.	Mouth.	215	485	2.26
Cedar River	Mississippi River.	Iowa	Cedar Falls, Ia.	Mouth of Iowa River.	176	323	1.84
Skunk River	Mississippi River.	Iowa.	Southeastern part of Hamilton Co., Ia.	Mouth.	203	551	2.71
Des Moines River . . .	Mississippi River.	Iowa.	Wisdom, Minn.	Mouth.	411	853	2.08
Crow Wing River	Mississippi River.	Minnesota.	Head waters.	Mouth.	105	500	4.76
Chippewa River	Mississippi River.	Wisconsin.	Head waters.	Mouth.	165	900	5.45
Upper Fox River	Lake Winnebago.	Wisconsin.	Fort Winnebago.	Oshkosh.	105	33.10	.32

(*d*) PERCOLATION INTO THE SOIL AND UNDERLYING STRATA.

The loss of the rainfall by percolation is extremely variable, and depends so largely on local conditions, that general rules are hardly applicable. Before considering it, we must examine more closely the geological conditions of this area, which modify the hydrographic conditions of the district. As the present geological features can be understood only after an examination of the history of their formation, a discussion of the historic geology of the region is appended.

GEOLOGY.

This entire region is underlain by Archean rocks of unknown thickness, which, as far as our knowledge goes and for the purpose of this discussion, may be regarded as the base rock or foundation on which rest the deposits to be considered. In Table XI these deposits are shown in their relative position, and their approximate thicknesses are stated.

Whether or not the rocks of the Archean formation are the primary rocks which constituted the original surface of the globe, is of little importance for the purpose of this discussion, as our present interest centers in the conditions now found and not in those which may have existed. It is sufficient to understand that among the Archean rocks of the region now under consideration, are found the earliest of the known rocks and that from these, directly or indirectly, all later formations have been formed.

The Archean rocks of this area are divisible into periods denoted by indications of a certain sequence in their origin and method of deposit. The earliest are the Laurentian rocks, consisting of granites, syenites and allied deposits. These were followed by the Huronian or Algoncian deposits, consisting of crystalline magnesian limestone, quartzite, slates and shists, and containing also the rich iron ore of Minnesota, Wisconsin and Michigan. Next, in this area, came the rocks of the Keweenawan period, consisting of sedimentary rocks, sandstones, conglomerates and shales, and eruptive rocks containing the rich copper deposits of the Superior region. Many of these rocks are flexed, folded, tilted and metamorphosed, showing evidence of upheavals and depressions of the earth's crust. Excepting of course the eruptive rocks, they show evidence of sedimentary origin, indicating their derivation from a more remote source, and that they are not themselves a portion of the original crust of the earth.

At the beginning of the formation of the later geological strata the Archean land was quite limited in extent in comparison with the present area of North America. Its supposed extent, within the boundaries of North America, is shown in Map No. 1, and its approximate outlines

within the Upper Mississippi Valley are shown in Map No. 2, which illustrates the supposed exposure of the Archean deposits during the early part of the Cambrian period while the Potsdam deposits were forming.

TABLE XI.

TABLE OF GEOLOGICAL FORMATIONS OF THE UNITED STATES, TOGETHER WITH THOSE REPRESENTED IN THE UPPER MISSISSIPPI VALLEY.

The numbers are those used in Macfarlane's American Geological Railway Guide.

AGE.	GROUP.	U. S. FORMATIONS.	UPPER MISSISSIPPI VALLEY FORMATIONS.	APPROXIMATE THICKNESS.
Cenozoic.	[20] Quaternary.	20 Recent.	[20d] Alluvium. [20c] Loess. [20b] Clay and sandy. [20a] Boulder clay.	Feet. 0 to 400
	[19] Tertiary.	19c Pliocene. 19b Miocene. 19a Eocene.	No representative. " " " "	0 0 0
Mesozoic	[18] Cretacious.	18c Upper Cretacious. 18b Middle " 18a Lower "	No representative. " " " "	0 0 0
	[17] Jurassic.	17 Jurassic.	No representative.	0
	[16] Triassic.	16 Triassic.	No representative.	0
Paleozoic.	[13-15] Carboniferous.	15 Permo-Carboniferous.	No representative.	0
		14B Upper Coal Measures.	Upper Coal Measures.	
		14A Lower Coal Meas'res.	14Ab Lower Coal Meas'rs. 14Aa Millstone Grit.	600 to 1,200
		13 Sub-Carboniferous.	13e Chester Group. 13d St. Louis " 13c Keokuk " 13b Burlington limestone 13a Kinderhook Group.	500 to 800 50 " 200 100 " 150 25 " 200 100 " 150
	[8-12] Devonian.	12 Catskill. 11 Chemung.	No representative. " "	0 0
		10 Hamilton.	10 Black Slate.	10 t 70
		9 Corniferous.	9 Devonian limestone.	10 to 120
		8 Oriskany.	8b Oriskany sandstone. Clear Creek limestone.	40 to 60 300 " 500
	[3-7] Silurian.	5-7 Upper Silurian.	7 Lower Helderberg. 5 Niagara limestone.	(?) 50 to 300
		3-4 Lower Silurian.	4b Cincinnati or Hudson River Group. 4a Trenton Group. 3b St. Peter sandstone.	100 to 250 200 " 400 50 " 250
	[2] Cambrian.	2c Calciferous.	2c Lower Magnesian or Oneta limestone.	80 to 825
		2b Potsdam.	2b Potsdam or St. Croix.	100 to 1,800
Azoic.	[1] Archean.	2a Keweenian.	2a Keweenian.	0 to 45,000
		1b Huronian.	1b Huronian or Algoncian.	0 to 13,000
		1a Laurentian,	1a Laurentian.	(?)

Since the beginning of geological history, the same agencies that are now wearing away the land surface and filling up the sea, have been at work, aided or hindered by the variations in climate which have marked the passage of time. The rains, with their dissolved gases, soften and wear the surface of the rocks. Taking up the soluble portions, they decompose and disintegrate the most lasting rocks. The sea, working at the coast line, tumbles the rocks into the surf, there to grind them into sand and pebbles, which again aid in the degradation of the adjacent land. Although the amount of this wear from day to day seems small, yet the accumulated work of these agencies, operating through the ages, has sufficed to pull down continents and to build up deposits, which, being elevated by upheavals of the crust, have formed new stretches of land surface, and these in their turn have been disintegrated and destroyed to form new and later deposits. By these agencies the Archean deposits which reared their heads above the Cambrian Sea were worn and disintegrated, and, being carried by torrential floods into the sea, formed the vast beds of Potsdam sandstone which underlie all of this area except that small portion where the Archean rocks still show their outcrop above the surrounding deposits.

During this age the principal part of the area was under the sea, which throughout Wisconsin was comparatively shallow and contained many quartzite islands of the Huronian formation, which yet rear their heads above the Potsdam outcrop. This Potsdam deposit consists mostly of sandstone derived from the broken quartz grains of the decomposed granites and allied rocks. These deposits, close to the Archean land, consist of coarse quartzose sand rock, very open and porous in its nature, and free from the iron, lime and clay, which in the higher strata are found associated with it. The Cambrian Sea held in its depths some of the earliest forms of animal life. Miriads of small shellfish, the remains of which may be seen in many of the Potsdam outcrops, inhabited its waters.

Although commonly spoken of as a single geological stratum, the Potsdam is by no means homogeneous in texture throughout. During its formation a vast period of time elapsed, very many disturbances occurred, and the circumstances of deposition of the different portions of the stratum varied greatly. These variations were almost or quite as great as those that marked the changes to subsequent geological ages.

The evidence of this, in portions of Wisconsin, is so marked that Prof. T. C. Chamberlain has classed the Potsdam strata of Central and Eastern Wisconsin in the following sub-divisions:

SUB-DIVISIONS OF POTSDAM DEPOSIT.

Sandstone (Madison)	35 feet.
Limestone shale and sandstone (Mendota)	60 "
Sandstone, calcareous	155 "
Bluish shale, calcareous	80 "
Sandstone, slightly calcareous	160 "
Very coarse sandstone, non-calcareous	280 "
Total	770 feet.

The thicknesses given are subject to wide variation. As a rule they thin out quite rapidly in Wisconsin northward from Madison, and increase in thickness to the southward into Illinois.

Prof. W. H. Winchell notes a somewhat similar classification in Minnesota. In a deep well drilled in East Minneapolis he found the following series of Potsdam rocks (See Geology of Minnesota, Vol. II, p. 279).

SECTION OF ARTESIAN WELL, EAST MINNEAPOLIS.

Sand (Drift)			42
Blue limestone, Trenton			28
White sandstone, St. Peter's			164
Red limestone	lower magnesian		102
Gray limestone	lower magnesian		16
White sandstone, Jordan	Potsdam	116	
Blue shale, St. Lawrence limestone	Potsdam	128	
Wite sandstone, Desbach	Potsdam	82	
Blue shale	Potsdam	170	
Sandy limestone	Potsdam	9	
White sandstone	Potsdam	130	
Sandy marl, Hinkley	Potsdam	8	
White sandstone	Potsdam	79	
Red marl	Potsdam	57	
Red sandstone	Potsdam	290	
			1069
			1421

Although the classification into these sub-divisions is warranted by well-defined beds around Madison, Wis, in eastern Wisconsin and in Minnesota, yet, owing to the thinning out or disappearance of these strata or by the multiplication of sub-divisions, the local variations are so great that in many places it is impossible to classify the strata found, under any general classification except the general name, Potsdam; for the limits of this formation, as a whole, are well and clearly defined. Further examples of the Potsdam stratification will show more clearly its variations. The following section of the Potsdam strata at Hudson, Wis., given by Prof. Chamberlain, illustrates this variation (See Geology of Wisconsin, Vol. IV, p. 113).

SECTION OF POTSDAM STRATA AT HUDSON, WIS.

20	feet	coarse, incoherent, red or white quartzose sand.
3	"	buff calcareous layer with shaly layer of green sand.
2	"	compact brown calcareous sandstone.
2	"	brownish-white sandstone.
8	"	incompact white sandstone.
2	"	brownish-white sandstone.
8	"	incompact white sandstone.
12½	"	white to buff sandstone.
8	"	white to buff sandstone, stained with iron.
12½	"	yellowish-brown sandstone, in mottled layers.
3½	"	buff friable sandstone, effervesces slightly.
10	"	incoherent sandstone.
27	"	shaly sandstone, effervesces slightly.
9	"	compact light buff sandstone, effervesces briskly.
5	"	dark brown sandstone.
10	"	dark brown rock, containing much calcareous material.
8	"	shades into strata above and below.
17	"	dark green shale.
10	"	dark buff sandstone.
5	"	buff calcareous sandstone.
5	"	green shale.
5	"	mottled shale.
13	"	light brown to white sandstone.
2	"	friable shale.
10	"	white sandstone.
3	"	green and white sandstone.
15	"	friable light buff and yellowish sandstone.
10	"	white sandstone.
245½		

Other sections encountered in Illinois, are as follows:

AT STREATOR.		FEET
Drift		30
Coal measures		211
Trenton limestone		203
St. Peter sandstone		225
Lower magnesian limestone		90
Potsdam:		
White sandstone	133	
White limestone	211	
White sandstone	37	
Dark gray limestone	50	
Fine reddish sandstone	15	
Dark gray limestone	13	
White and brown sand	1	
Gray limestone	18	
White and brown sandstone	168	
Blue shale	100	
Dark limestone	73	
Variegated sandstone	187	
Soft limestone	60	
Variegated shales	158	
Dark red sandstone	80	
Blue shale	50	
Bluish drab and buff limest.	383	
Totat depth in Potsdam		1737
Total depth		2496

AT ROCKFORD.		FEET
Drift		125
Trenton limestone		30
St. Peter sandstone		225
Lower magnesian limestone		105
Potsdam:		
Green sandstone	5	
Red sandy shale	72	
Gray sandstone	148	
Blue shale	25	
Gray sandstone	40	
Red sandstone	25	
White sandstone	335	
Red shale	2	
White sandstone	13	
Red shale	2	
White sandstone	13	
Red shale	1	
White sandstone	9	
Red shale	20	
White sandstone	80	
Gray sandstone	45	
Yellow sandstone	20	
Red shaly sandstone	105	
White sandstone	90	
Red shale	275	
White sandstone	171	
Total depth in Potsdam		1486
Total depth		1981

At Ottowa, Ill.		Feet
Drift		35
St. Peter sandstone		130
Lower magnesian limestone		145
Potsdam:		
Sandstone	110	
Free limestone	175	
Sandstone	260	
Blue shale	120	
Hard sharp sandstone	100	
Sandstone	115	
Shale	360	
Sandstone	290	
Total depth in Potsdam		1530
Total depth		1840

At Joliet, Ill.		Feet
Niagara limestone		230
Hudson River shale		68
Trenton limestone		334
St. Peter sandstone		217
Red shale		40
Lower magnesian limestone		450
Potsdam:		
Sharp sandstone	175	
Blue shale	50	
Sandy limestone	125	
Shale	230	
sandstone	150	
Total depth in Potsdam		730
Total depth		2066

As indicated in the foregoing tables, the Potsdam varies greatly in its character throughout its extent, not only from shale and limestone to sandstone, but also in the character of the sandstone, which is mostly fine-grained, but becomes coarse-grained in its lower strata, and passes into a conglomerate near its margin, the shore of the ancient Archean land. As may be understood from its physical character, it readily transmits the water which it receives at its outcrop, either from rains or from the numerous streams which flow over its exposed surface, the extent of which may be judged from the maps. The outcrops of the Potsdam occupy about 14,000 square miles in central Wisconsin, extending in a crescent-shaped tract around the Archean outcrop.

The Lower Magnesian or Oneta Limestone.—While the variation in the circumstances attending its deposition caused considerable differences in the various strata of which the Potsdam deposit is composed, a more radical variation gave rise to a still more remarkable change in the formation, and the lower magnesian limestone resulted. This formation is a dolomitic limestone, coarse, irregular in stratification, often interstratified with shale or sandstone layers and limestone breccia, which last, occurring in clusters or heaps, often gives the upper surface a billowy appearance and causes it to vary greatly in thickness. The variation in thickness seems to be more marked in Wisconsin than elsewhere.

Although undoubtedly cracked and fissured to some extent, it seems to be in general free from these disturbances and to offer a quite uniform and homogeneous mass to prevent the upward passage of the waters contained in the Potsdam stratum below it. This stratum is found from 65 to 260 feet thick through Wisconsin and is from 105 feet to 170 feet thick in northern Illinois. It seems to thicken quite rapidly to the southward, and is found to be 490 feet thick at Joliet, 500 feet thick at Streator and 811 feet thick at Rock Island. A flow

of water, which may be derived from the underlying Potsdam sandstone, is sometimes found in the softer portions of this stratum.

The St. Peter Sandstone (see Map No. 3).—Above the lower magnesian limestone lies a remarkably uniform quartzose sandstone. It is uniform in material and thickness, and quite covers all the irregularities in the surface of the underlying limestone, except at some points in Wisconsin where it is entirely pinched out; the Trenton limestone lying directly on the lower magnesian. Its average thickness, throughout the territory under discussion, is probably about 200 feet, although in Wisconsin Prof. T. C. Chamberlain estimates its average thickness as only about 80 feet. This deposit is supposed to have been formed in a shallow sea by the decomposition of the Archean and Potsdam rocks. The hypothetical condition of the Upper Mississippi Valley during the formation of the deposit is shown in Map No. 3. No fossils have been found in this rock, and its formation marked an epoch probably unfavorabe to the existence of life.

This stratum has an outcrop of about 2,000 square miles in Wisconsin, and also crops out at several points in Illinois along a line of upheaval which passes southeastwardly from Stephenson County to the vicinity of La Salle, bringing the St. Peter to the surface along the Rock River at Oregon and Grand Detour, and along the Illinois River from La Salle to Ottawa. The lower magnesian limestone is also brought to the surface at Utica by this uplift. The St. Peter sandstone is an important water-bearing stratum, although its outcrop is so low that the pressure of its water is usually much less than that of the Potsdam.

Trenton Age.—Although apparently no life existed during the formation of the St. Peter sandstone, yet conditions favorable to the existence of life again returned, accompanied by geographic changes in the relation between the sea and the land, and extensive beds of limestone were again deposited. These constituted the limestones of the Trenton group, which may be divided into various substrata more or less distinct in character. Of these the Galena limestone is, perhaps, the best known, but for the purpose of this paper the Trenton may be considered as a whole, inasmuch as its general character is approximately uniform.

The Cincinnati or Hudson River Formation.—Further change in the conditions of deposition gave rise to turbid floods of more or less intermittent and local occurrence. These again altered the character of the deposit, and the Cincinnati or Hudson River shale resulted. This consists of clay shale interbedded with more or less limestone.

The Niagara Formation (Map No. 4).—Next followed the limestone deposits of the Niagara period, divisible into strata of more or less

local importance. This deposit occurs at different points in the valleys, and embraces the Joliet, Lemont, Naperville, Waukesha and Animosa limestones. A general idea of the supposed extent of the land in the Upper Mississippi Valley during the formation of the Niagara limestone is shown in Map No. 4, which illustrates also the gradual elevation and extension of the land surface.

The Devonian Formation.—On the Niagara formation were deposited the rocks of the Devonian period, consisting of limestone rocks of no great interest in this discussion.

At this time a large portion of the area under consideration had been elevated above the sea, and the last remaining series of deposits which we shall here consider was in this area more limited in extent than any which preceded it.

The Carboniferous Age.—The carboniferous age which followed is illustrated by Map No. 5, which shows the further recession of the sea and the consequent limitation of the strata then under process of formation.

This age ushered in an epoch of life very different from any which had preceded it. Its deposits were comparatively local in character, and although they have in a general way been correlated, yet there is a greater variation in these strata than in those of any preceding deposits. Especially is this true in those of the coal measures proper. These deposits seem to have been made in shallow seas, lakes or swamps of limited extent, rather than in a broad and deep sea such as those in which most of the preceding deposits had been formed. Hence, great local variations are observable and the strata have commonly a much more limited geographic extent. This age witnessed the formation of extensive beds of limestone, sandstone, shales and coal, a condensed section of which, taken from Vol. VII, Geological Survey of Illinois, is here inserted.

Condensed Section of Illinois Coal Measures.

Sandstone and shale with 6-inch seam of coal	10 to 200 feet.
Coal No. 16	1½ to 3 feet.
Sandstone and shale	75 to 100 feet.
Coal No. 15	1 to 3½ feet.
Sandstone and shale	50 to 60 feet.
Coal No. 14	1½ to 2 feet.
Sandstone and shale	80 to 90 feet.
Coal No. 13	0 to 3 feet.
Sandstone and shale	75 to 80 feet.
Coal No. 12	0 to 1 foot.
Shales and limestone	20 to 25 feet.
Coal No. 11	0 to 1 foot.
Shales	30 to 40 feet.

Coal No. 10	0 to 1 foot.
Sandstone, shales and limestones	80 to 90 feet.
Coal No. 9	0 to 2 feet.
Sandstone, shale and limestone	60 to 70 feet.
Coal No. 8	1 to 2 feet.
Sandstone, shale and limestone	80 to 100 feet.
Coal No. 7	1 to 9 feet.
Sandstone, shale and limestone	20 to 30 feet.
Coal No. 6	0 to 6 feet.
Shale and limestone	20 to 30 feet.
Coal No 5	4 to 6 feet.
Sandstone and shale	60 to 80 feet.
Coal No. 4	0 to 5 feet.
Shales and sandstones	60 to 70 feet.
Coal No. 3	0 to 4 feet.
Shales	40 to 60 feet.
Coal No. 2	1½ to 5 feet.
Sandstones, shales and limestones	30 to 80 feet.
Coal No. 1	1 to 5 feet.
Sandstone and conglomerates	20 to 150 feet.
Lower carboniferous limestone	0 to 1,500 feet.

GENERAL CHARACTERISTICS OF THE STRATA.

It should be understood that lines of exact demarkation seldom exist between the various strata. One stratum usually passes gradually into another. Changes in the controlling influence which modified the deposition were usually not radical and they only obtained gradually. Thus, in passing from sandstone to limestone, the upper strata of the sandstone will usually be found somewhat calcareous and the lower strata of the limestone somewhat silicious.

A like condition applies to the character of a stratum as varying throughout its geographic extent. The conditions at one point may have been such as to favor the formation of limestone deposits, while those at a point more or less remote may, during the same period, have been favorable to the formation of shale. We thus find widely different strata belonging to the same age. Hence a stratum may within a short distance merge from a sandstone into a limestone, from a limestone into a shale or the reverse, or from a coarse-grained stone to a fine and more impervious one. Or a stratum may even have been entirely lost by reason of a local elevation which raised the sea bed at that point above the sea level, thus preventing deposits, or by the existence of local oceanic currents which might accomplish the same result. The more widespread the conditions controlling deposition, the more uniform is the character of a stratum throughout its extent. The character of the rock deposit which we may encounter in drilling is often highly problematic, and it is only by an extended examination of facts as they have been found

to exist, and by their careful correlation, that we may arrive at conclusions as to what we must expect in new and untried localities. The farther the point in question lies from those where the character of the sub-strata is known, the greater is the uncertainty respecting it.

The original extent of the various strata of the district under consideration was much greater than the present geological map of the region would indicate. Hundreds of feet of strata have been disintegrated and eroded by drainage waters. The Hudson River shale, while now encircling Central Wisconsin and Central Northern Illinois as a narrow belt (see Map No. 6), undoubtedly once covered a much greater area, as did the strata of the Niagara group. The section through Elk Mound shows the present geological condition, while the prolongation of the limiting lines of the strata would show their probable original extent. Maps Nos. 2 to 5, in conjunction with the general geological map (Map No. 6) of this area, will give a general idea of the vast erosion accomplished by the drainage waters since these strata appeared above the sea.

It must also be understood that the strata, although originally deposited as more or less uniform sheets, each overlying the strata below, do not exist in this uniform condition at present; for many disturbances, caused by upheavals and depressions in the crust, have opened cracks and fissures and have caused relative displacements of the strata, amounting in some cases to hundreds of feet. The principal axes of disturbance in this area are shown on Map No. 7. The extent of the cracks and fissures caused by these disturbances of the strata may be judged by a visit to any quarry. Their existence largely modifies the hydrological conditions of the various strata, frequently permitting the passage of the waters from one stratum to those below or above, and in the latter case, giving rise to springs.

The underlying Archean rocks slope downward in all directions from their outcrop in the extreme northern portion of this valley, being about 2,000 feet above sea level at their highest outcrop, and perhaps fully as much below sea level at their lowest point. As a rule, the superincumbent strata follow this general slope. The Potsdam strata, however, thicken rapidly to the southward, as does the lower magnesian above it, so that the higher strata have not as great a rate of inclination as the dip of the Archean rocks would indicate.

The north-and-south section accompanying Map No. 6 illustrates these remarks, and shows, moreover, that the surface follows the general dip of the strata at present, as it has done through all past geological ages; the outcrops of the older geological deposits being found at the higher elevations. In traveling from the original Archean nucleus in any direction the traveler will descend in elevation while he ascends

in geological succession, passing over each of the deposits already described as he approaches the sea level.

The dip of a stratum causes the flow of its imbibed waters from its outcrop toward the sea, and from these sources flow springs and artesian wells where the stratum is intercepted by cracks or fissures or is artificially pierced by the drill.

During the ages here briefly reviewed, this territory had gradually arisen from the ocean. The carboniferous strata mark the last age of submergence in this area, with the possible exception of certain minor cretaceous areas in the western portion of the Mississippi Valley, areas which are of comparatively little consequence in this discussion.

With the earliest appearance of the strata above the sea the formation of a drainage system began. The atmospheric agencies disintegrated the softer portions of the strata and carved the rocks into various forms as their varying hardness permitted. The drainage waters carried the residuary matter to the sea, thus excavating deep drainage valleys, and forming the later strata by the deposition of the material. The extent of this drainage erosion has already been briefly considered.

The subsequent alteration of these drainage valleys has rendered it almost impossible to conceive of their early character and extent. The hill-tops were higher and bolder than at present. The valleys, deeper, more narrow and more rugged, occupied in many cases locations quite different from those now occupied. The Lake Michigan valley was then occupied by a river which flowed from the north through the present southern extremity of the lake, at an elevation some hundred feet below the present lake level. This river, with a southwesterly course and passing probably not far from the present site of Bloomington, Ill., emptied its waters into the Mississippi near the present mouth of the Illinois River. A light soil covered the valleys and the depressions of the hills, furnishing a scant vegetation for the sustenance of animal life. The mammoth and the mastodon, whose descendant, the modern elephant, is no longer native of this continent, roamed through these early valleys, probably a co-inhabitant with primitive man.

The Mississippi River occupied to a considerable extent its present course. To this, however, there are local exceptions, notably at St. Paul, La Crosse, Rock Island and Keokuk, where the rock-bottomed rapids testify to a diversion from the ancient bed. The river then probably drained a much larger territory than at present. It also flowed at a level probably from 100 to 250 feet lower than its present one. It is difficult to picture the Upper Mississippi Valley as it then existed, but those who are familiar with the driftless area of Wisconsin, north and west of the Wisconsin River, including the dells and country about Devil's Lake, can form some conception of the early topography of this

whole area. This region of Wisconsin has been less altered than any other in the district considered ; yet its valleys, which were then much deeper than now, have been more or less completely filled by the fluvial deposits of the drift period.

The principal existing streams of this area, and to some extent their lateral valleys, were features of the topography of the age we are now considering, their appearance has been greatly modified by the subsequent events of the Glacial period.

THE GLACIAL PERIOD.

From causes not thoroughly understood, the consideration of which is unnecessary for the purpose of this paper, there followed periods of great cold ; of long winters and short summers and perhaps of greater average precipitation than at present, which fell as snow over the arctic and higher temperate regions and which the heat of the short summer was wholly inadequate to melt. The result was the accumulation of vast snow fields, thousands of feet in thickness, similar to those which now exist in Greenland and Alaska and in the higher altitudes of the Alps the Himalayas and the Rocky Mountains. The weight of the superincumbent mass, greatest in depth in the north where the summer heat never penetrated, not only compressed its lower layers into ice, but forced them to flow in great glaciers to the southward. Their extent in this direction was limited only by the conditions of equilibrium between the melting of the ice mass and its motion. The effects of the flow of these vast ice rivers over the irregular and deeply marked drainage depressions can be easily understood. The rocky hillsides were worn and broken into dust and fragments ; huge boulders were torn off and transported hundreds of miles ; and the valleys were filled up with the accumulating débris, which was more or less sorted and arranged by the sub-glacial waters. At least two epochs of glaciation, more or less distinct, can be traced in the Upper Mississippi Valley. See Maps Nos. 8 and 9. These have been perhaps the most marked causes in the creation of the present conditions, at least in so far as they are related to civilized life. To this period the agricultural lands of Minnesota, Iowa and Illinois owe their character and fertility, and their ability to maintain the population now within their borders. The drainage system was altered and the topography was greatly changed and rewrought. Not only were the valleys filled up and the hills cut down, but a new class of topographical features was introduced.

While flowing water can transport only débris of a coarseness depending upon the velocity, moving ice will transport the largest rocks as well as the finest material. On melting, the ice deposits its heavier material, most of the finer particles being often lost in the floods which

result from the melting of the ice. The material pushed up or deposited in this manner by the ice is termed a moraine, and when it marks the termination of the ice-flow, a terminal moraine. Such is the Mettle Moraine, which extends across the entire territory here considered. When formed on the *side* of the moving ice capes it is termed a lateral moraine, and two of these may be joined into a medial moraine.

Upon the melting of detached ice masses covered by extensive deposits of moraine material, this material is deposited about their edges, forming kettle holes, which result in lakes and swamps.

The streams of water resulting from the rains and melting ice, frequently cut open channels in the glaciers and sweep into it vast quantities of material which is there worked over and sorted by the flood, and deposited as a delta at the end of the glacier, or in long lines between the valleys of ice, where it is left, on the melting of the ice, as elongated ridge-like deposits called kames.

Map No. 8 gives a hypothetical view of the conditions of the Upper Mississippi Valley during what is called the first glacial epoch, or at the time when the ice had reached its greatest southern extension. The limits of the ice are still marked by ranges of hills of morainic material, the nature and character of which offer conclusive evidence of its origin. Many of the topographical features of the first glacial epoch have been greatly modified by subsequent glacial events and by atmospheric and aqueous erosion during the time which has since elapsed. The kettle holes and lakes have been gradually filled and they are now mostly swamps or peat-bogs, and deep lines of drainage have been cut through the glaciated area. This process has been largely aided by the drainage waters of the second glacial epoch. During that epoch the extent of the ice capes was much more limited than in the first, as may be seen by reference to Map No. 9, and, as its period was more recent, its topographical features are more marked. Within the kettle moraine which marks its limits are found the numerous small lakes which form so striking a feature of Wisconsin and Minnesota scenery.

With the recession of the ice capes began the development of a new drainage topography. The floods which came from the melting ice, inundating great tracks of country, especially along the Mississippi River, gave rise to lacustrine deposits of considerable depth, known as loess, a deposit consisting mostly of sand with some little clay, and so pervious as to offer little hindrance to the flow of drainage waters. The glacial waters had begun to excavate channels for their flow in their earlier deposits, and this process was continued in the lacustrine districts as the lacustrine conditions ceased to prevail. The old Michigan valley had been filled at the southern extremity of the present lake, and the waters being yet dammed in by the receding glacier from the present

outlet of the lake, found a passage through the present valley of the Illinois River. Lake Agassiz, the progenitor of the present Lake Winnebago, with an area equal, at least, to the combined area of Lakes Superior, Michigan and Huron, flowed south through the valley of the Minnesota River, and through the lake which then existed in a portion of that valley, into the Mississippi. The other rivers of this area, while early receiving considerable drainage water from the melting ice, soon lost these waters as the ice receded, and settled down to act as the drains of their present respective drainage areas.

The hypothetical condition of the country at one period in the recession of the glaciers is shown in Map No. 10. This shows the location and outline of the southern extension of the glacial Lake Agassiz, and also the outline of Lake Minnesota. The latter, while shown on the map, was probably either entirely or partially drained at this period. The glacial River Warren occupied the present valley of the Minnesota River, and to its agency the dimensions of the present valley are due. Map No. 10 also illustrates the main drainage features existing at this period, at which time the glacial River Warren drained Lake Agassiz, the Illinois River and Lake Michigan, and through the latter probably Lakes Superior, Huron and Erie. At a somewhat earlier date, Lake Superior was drained through the Brule and St. Croix Rivers directly into the Mississippi, as shown by the dotted lines at the western end of the lake; but, as the glacier receded, the outlet from Au Traine Bay to Little Bay de Noquet was uncovered, and at the period illustrated by the map the outlet was probably at this point. Later the discharge probably took place across the peninsula further to the east. Lakes Huron and Erie also probably drained into Lake Michigan at this period. It may, however, be considered doubtful whether all of the features shown on Map 10 were contemporary.

At an earlier period in the recession of the ice cape the Chippewa, Black, Wisconsin, Rock and Fox Rivers had received from it a portion of their drainage waters, which had undoubtedly outlined the channels in which they now flow; but at the time illustrated in this map they had lost these waters and they carried only the flow due to the rainfall and drainage of their own watersheds.

The vast floods from the melting ice had greatly changed the earlier glacial deposits in these valleys. The heterogeneous masses of clay, stone and sand, were, in many cases sorted, rewrought and redeposited. As the ice still further receded, the present outlet of Lake Michigan was uncovered, as was also the Hudson Bay outlet to the valley of the Red River of the North. These outlets being at lower elevation than those offered by the Illinois and Mississippi Rivers, these rivers also lost the glacial drainage which hitherto, as the only outlets, they had been

receiving from the melting ice capes. In these rivers the results due to the loss of the drainage waters was much more marked and the changes in their conditions were more radical than in the smaller rivers of this area.

As the drainage valleys were deprived of waters from the melting ice, their carrying power decreased and they began to build up their beds, which they had formerly excavated so as to form a valley commensurate in size and inclination with their modern capacities. The local streams, dependent only on local rainfall and drainage area, had also begun to develop as the country was uncovered by the receding ice. These in the main followed such depressions as the ice capes had formed. Rarely, if ever, in the glacial or local drainage streams, were the earlier drainage valleys closely followed throughout their entire extent. The old valleys having been filled, frequently to their tops, it was often as easy and as natural for the modern stream to pass from valley to valley between two hills which formerly separated valleys, as to continue in its ancient course.

As the waters cut through the drift, the rocky hillsides were frequently encountered, and these caused a diminution in the amount of cutting by the stream, while the excavation below still went on. Thus have been formed many falls and rapids both in the Mississippi River and in its tributaries.

The drift itself, as modified by the glacial waters, possesses largely a locally developed stratification, ordinarily somewhat limited in its geographic extent.

The following sections of the drift show its variation in depth and general character, which will be seen to be subject to great local differences.

SECTIONS OF DRIFT.

Bushnell, McDonough Co., Ill.

Depth in feet.	Material.
12	Yellow clay.
8	Yellow clay and sand.
25	Yellow clay.
15	Blue and yellow clay.
18	Blue clay and sand.
29	Blue clay.
3	Blue clay and sand.
4	Sand.
114 feet.	

Bloomington, McLean Co., Ill.

Depth in feet.	Material.
10	Soil and brown clay.
40	Blue clay.
60	Gravel.
13	Black mucky soil.
89	Hardpan.
6	Black soil.
34	Blue clay.
2	Quicksand.
254 feet.	

Mt. Carroll, Carroll Co., Ill.

Depth in feet.	Material.
2	Soil.
13	Yellow clay.
2	Blue clay.
15	Reddish clay and gravel.
2	Tough blue clay.
3	Coarse stratified gravel.
11	Pure yellow sand.
5	Black mucky clay.
53 feet.	

Clinton, De Witt Co., Ill.

Depth in feet.	Material.
15	Soil and yellow clay.
30	Hard blue clay.
2	Black mould.
8	Drab clay.
8	Black mould and drift wood.
16	Drab clay.
2	Drift wood, etc.
26	Drab clay.
12	Hardpan.
10	Green clay.
133 feet.	

Lake City, Minn.

Depth in feet.	Material.
2	Black soil.
40	Yellow clay.
160	Gravel and sand.
5	Fine loam clay.
207 feet.	

Minneapolis, (Lakewood Cemetery.)

Depth in feet.	Material.
135	Gravel and sand.
3	Yellow clay.
74	Blue till.
36	Gravel and sand.
8	Boulders.
256 feet.	

Within the driftless areas, the ice floods had filled the lower valleys with detritus brought down by the flood waters, and had thus modified, although to a less extent, the topography of this region.

The major part of the glaciated area, outside of the kettle moraine, is, however, an extended plain, modified by other morainic deposits and by the drainage valleys, which have since been somewhat developed. At the close of the glacial ages the ancient topography had been destroyed; while the new was yet in its infancy, and it is still but slightly developed; so slightly, in fact, that imperfect drainage is the rule on the plain between the rivers.

The common law of topographical development in the glacial area is readily understood. The circumstances of glaciation establish the limits of the watersheds; the waters subsequently flowing from the receding ice frequently outlining the location of the streams themselves. The flood waters carve their valleys in proportion to their amount and elevation, and gradually excavate them until their fall from source to mouth is only sufficient to cause a flow of their waters, carrying perhaps more or less of excavated silt in time of flood. The water has then reached its base level, and can go no lower, but works backward and forward across the valley, widening but not deepening it. The depth to which a stream can excavate its valley is then subject to the controlling features of its point of discharge, which in the case of the rivers of this region is formed by the Mississippi River and Lake Michigan. Hence,

the nearer these outlets a valley is located, the more marked is its character and depth. Few rivers in this area have reached their base level, for the time since the glacial age has been too short. The Illinois River, in its lower course (as has been already mentioned), is an exception, the glacial waters having reduced it to a lower grade than is suitable for the discharge of its present waters laden with their normal burden of silt. Hence the low lands are flooded and the silt is deposited, gradually raising the bed of the river; and this process, if allowed to proceed unobstructed, will finally raise the lower river to its normal base level. Thus have been formed the surface and underlying rocks of the Upper Mississippi Valley. Volumes have been written descriptive of the ages here so briefly reviewed and of the conditions which we have been obliged to pass with a glance, and to these the reader is referred for further details. Enough has been said, however, to fix the general sequence of events and the general geological condition. For purposes of practical use, each district must be studied in detail and the whole subject examined with reference to the particular questions involved.

The Potsdam sandstone is one of the most important of the formations embraced in the territory under discussion, and its character has been examined at some length. From this source are derived numerous artesian and deep wells, which have been developed throughout the area shown on the general geological map, No. 6.

As a source of water, the St. Peter sandstone is next in importance in this area. This deposit lies above the Potsdam, being separated from it by the lower magnesium limestone, and is first encountered by the drill. The elevation of its outcrop being less than that of the Potsdam, its waters have not usually as great a head and consequently it does not as often furnish flowing waters.

It has already been stated that the drift sheet which covers a large proportion of this area contains more or less extended deposits of sand and gravel which frequently offer available sources of water. These deposits are sometimes so extended that they may produce all of the phenomena observable in the lower strata, such as artesian flows, as that of Bell Plain, Iowa, and De Kalb, Ill., and copious springs at numerous points within this valley. The irregularity in the deposition of these deposits makes the watershed of any particular supply hard to determine. Its determination is, however, a matter of considerable importance, especially where it flows from districts in which it may receive organic contamination.

In considering the hydrological conditions of the various strata it should be noted that all are to some extent water-bearing. Even where the ratio of absorption is comparatively insignificant, the cracks and fissures often play an important part. The writer is able to furnish

only a limited number of observations on the rocks of the area here considered, and these are given in Table XII, together with data of other and similar rocks from other localities.

Most of the rocks mentioned in the following table are from quarries furnishing building stone. They are, therefore, better and less porous than the average bed rock.

TABLE XII.

Table Showing Percentage of Absorption (by Volume) of Various Geological Strata.

Formation.	Location.	Water in 100 parts of rock.	Authority.
Sandstone	Grand Beauchamp, France	13.15	M. Delessee.
Sandstone, another specimen	Grand Beauchamp, France	4.37	M. Delessee.
Calcareous freestone	Grand Beauchamp, France	18.03	M. Delessee.
Lower tertiary, sandstone (pure quartzose)	Grand Beauchamp, France	29.00	M. Delessee.
Upper chalk	Ivry, France	24.10	M. Delessee.
Devonian limestone	Boulogne, France	0.08	M. Delessee.
Oolite sandstone	Cheltenham, England	23.98	E. Wetherel.
Oolite limestone	Cheltenham, England	12.15	E. Wetherel.
Old red sandstone	Gloucestershire, England	11 60	E. Wetherel.
Hornblende granite	East St. Cloud, Minn.	.42	G. P. Merrill.
Gabbro	Duluth, Minn.	.29	G. P. Merrill.
Dolomite	Joliet, Ill.	1.06	G. P. Merrill.
Limestone	Quincy, Ill.	.55	G. P. Merrill.
Limestone	Quincy, Ill.	1.35	G. P. Merrill.
Sandstone	Fond du Lac, Wis.	4.81	G. P. Merrill.
Dolomite	Lemont, Ill.	1.12	G. P. Merrill.
Dolomite	Winona, Minn.	4.76	G. P. Merrill.
Dolomite	Red Wing, Minn.	2.5	G. P. Merrill.
Dolomite	Mantorville, Minn.	5.55	G. P. Merrill.
Limestone	Big Sturgeons Bay, Wis.	.25	G. P. Merrill.
Sandstone	Ft. Snelling, Minn.	6.25	G. P. Merrill.
Sandstone	Jordan, Minn.	12.5	G. P. Merrill.
Sand and Gravel		33 to 40	R. J. Hinton
Dry clay		12.	R. J. Hinton.
Trenton limestone	Rockford, Ill.	2.10	D. W. Mead.
Galena limestone	Rockford, Ill.	4.2	D. W. Mead.
Berea sandstone	Berea, Ohio	6.6	D. W. Mead.
Bedford limestone	Bedford, Ind.	4.4	D. W. Mead.

From what has been said concerning the variation in the character of a stratum throughout its geographical extent, it will readily be understood that no simple statement of ratio of absorption will furnish a sufficiently reliable indication of the water-bearing qualities of a stratum in all places. We know, however, that the strata are saturated to an unknown depth, the amount of water varying with the porosity of the strata, and with their physical condition as regards cracks and fissures. This area, like many others, is marked by an alternation in the deposi-

tion of rocks varying largely in porosity, strata of high porosity frequently lying between those comparatively impervious. This variation is somewhat equalized by cracks and fissures, but the difference is still so marked as to create a great difference in the character of the flow.

The outcrop of these highly pervious strata at the higher elevations in the valley gives rise to hydrostatic pressure within the strata, a pressure which is not wholly equalized by the transfusion of waters due to porosity or to rupture of the strata. Hence, in the lower portions of the valley, these waters often come to the surface with considerable head through natural channels as springs, or through artificial channels as flowing wells.

The existence of water in the strata above renders most efficient aid in confining these low drainage waters. Without this their immense pressures would undoubtedly bring them to the surface. Ordinarily, the difference in elevation between the head of the deeper waters and that of the ground water is very limited. At Ottawa, Ill., however, it amounts to about 180 feet, and at Aurora, Ill., to 90 feet. Other data concerning differences in heads may be seen in Table XIII, which gives many data concerning the deep wells in this area. Table XIV gives the thickness of the various geological deposits encountered in sinking many of the artesian wells in this territory. The locations of many of the artesian and deep wells are shown on Map No. 11.

TABLE XIII.—PHYSICAL DATA OF ARTESIAN AND DEEP WELLS OF THE UPPER MISSISSIPPI VALLEY.

ILLINOIS.

Locality.	Owner.	Depth of well.	Diameter of well.	Pressure at surface.	Flow per day.	Remarks.
		Feet.	Inches.	Pounds.	Gallons.	
Aledo	City	3,133				Water from 1,200 feet rises to within 60 feet of surface; at 3,000 feet universal water rises to within 26 feet of surface.
Amboy	City	2,012				
Aurora	City	1,388 2,440	6 and 8 5, 8, 10 & 15	40		From St. Peter and Potsdam sandstone.
Austin	City	1,205				
Belvidere	City	1,932	*		288,000	Flow given is at point 6 feet below surface. Well is connected direct with pumps.
Berry	City	2,510				
Chicago	American Brewing Co.	2,100				Into Potsdam.
Chicago	Armour & Co.	1,200 to 1,600				Several wells.
Chicago	Anglo-American Packing Co.	1,300 to 2,200				Several wells.
Chicago	Swift & Co.	1,200 to 2,700				Several wells.
Chicago	Auditorium	1,250				
Chicago	C. & G. T. R. R.	1,700				
Carthage	City	1,800				
Canton	City	2,500				
Dixon	Condensed Milk Co.	1,500 1,700	6 8		756,000	Flow given is from both wells, and is derived from the Potsdam. Temperature, 60° Fahr.
De Kalb	City	850 2,500	6, 8, 10 & 14 6		90,000	This amount is pumped by deep-well pump. The deeper well is into the Potsdam, but is not now in use, all of the water coming from the St. Peter.
East Dubuque	City	910	5	42	605,000	
Fairbury	City	2,002				
Fulton	City	1,246	5	26½	864,000	
Galena	Water Works Co.	1,509	8			Flow from Potsdam. Well connected direct with pumps.
Geneseo	City	800	6			Temperature, 49° Fahr.
Harlem (Cook Co.)	City	1,017				Principal yield from strata 120 feet below surface.
Henry	City	1,355				
Hinsdale	City	864				Flowing well.
Ipava	City	1,570	4			Water rises to within 16 feet of surface.
Jerseyville	City	2,003	6			St. Peter, not flowing.
La Grange	City	2,014				
Lake Forest	C. B. Farwell	2,000				
Lake Forest	J. L. McCormick	1,600				
Marseilles		100	3			From St. Peter, sandstone.

There are numerous other deep and artesian wells in and about Chicago. Those given indicate fairly the depth required.

* 8 inches diameter for the first 1,200 feet; 6 inches for the remainder.

Moline	Paper Mill	1,810	5	60	890,000	
Monmouth	City	1,227	4 and 6			Water stands 50 feet from surface.
Oak Park	Water Works Co.	2,180	6		175,000	Flow from four wells by gravity to pumping pit. Temperature, 66° Fahr.
Princeton	City	2,515	8			Temperature, 64° Fahr.
Polo	City	2,098				
Park Ridge	City	1,500	3½ and 6			Water rises to within 8 feet of surface.
Peru	Plate Tin Works	1,360	8			
Rockford	City	1,530	5, 6 and 8		168 000	Temperature, 60° Fahr. Water mostly from Postdam.
		1,320	6 and 8		208,000	
		1,996	6 and 8		316,000	
		1,300	6 and 8		370,000	
		1,379	6 and 8		234,000	
		400	8			
Rock Island	Mitchell & Lynde			37½		Water pumped from St. Peter sandstone obtained a slight flow at 70 feet; 8 lbs. at 700 feet; 37½ lbs. at 1,124 feet.
Rushville		2,500				
Riverside	City	1,370	3½			
Sterling	Water Works Co.	1,450	*			Temperature, 62° Fahr. Flow from Potsdam.
Streator	City	2,496		17		Flow of saline water from Potsdam.
South Evanston	City	2 00	5			
		1,602	5 and 6			
Savanna	City	1,432				
Warsaw	City	844	6	42½	432,000	From St. Peter sandstone. Temperature, 60° Fahr.
Waukegan	City	1,134				Flowing well from St. Peter sandstone.
IOWA.						
Belle Plaine	City					Flow from drift.
Boone	City	3,000	†			
Clinton	Water Works Co.	1,674		20	2,160,000	
Clinton	Water Works Co.	1,035	5	30		
Clinton	Water Works Co.	1,216	5	30		
Clinton	Lamb & Son	1,205	5½	15		
Clinton	Clinton Paper Co.	1,065	5½	15		
Cedar Rapids	Water Co.	1,300				
		2,100				
Centreville		2,500				
Council Bluff	Geis Brewing Co.	840				
Dubuque	Steam Co.	802	4	37½	271,400	There was a large decrease in pressure and flow in all Dubuque wells when the 10-inch water-works well was sunk.
Dubuque	Julian House	896	4	47	671,200	
Dubuque	Larimer House	1,057	5	25	576,000	
Dubuque	Butchers' Association	967	5	58	815,200	
Dubuque	Water Works Co.	1,310	10	20		
Dubuque	Greenwood Cemetery	2,000	3	8	57,600	
Dunlap		1,535				
Davenport	Glucose Co.	750	5	10	317,000	This amount is obtained by pumping water from Potsdam and St. Peter. Temperature, 58° to 60° Fahr.
		2,150	5	57	501,000	

* 8 inches diameter for the first 1 000 feet; 6 inches for the remainder.

† 8 inches diameter for the first 1,300 feet; 5 inches for the remainder.

TABLE XIII.—Physical Data of Artesian and Deep Wells of the Upper Mississippi Valley.

IOWA.—Continued.

Locality.	Owner.	Depth of well.	Diameter of well.	Pressure at surface.	Flow per day.	Remarks.
		Feet.	Inches.	Pounds.	Gallons.	
Jefferson	. . . .	2,020				
Keokuk	Band Park	900				
Monticello	City	1,200				Forty feet into the Potsdam.
Mason City	. . . .	600 to 1,400				
Montrose	Park Association	850				
Ottumwa	John Morrill & Co.	1,554				
Oskaloosa	City	2,517				
Tipton	City	2,700				
Vinton	City	1,2[illegible]0	8	8	90,000	Temperature, 56° Fahr. Flow by gravity to pumping pit.
West Liberty	City	1,768			170,000	Well is 30 feet above business portion of town.
Washington	City	1,610				
WISCONSIN.						
Appleton	. . . .	430	6			
Burlington	City	1,008	5		144,000	Flows to reservoir.
Fond du Lac	B. Wild & Co.	326		23	69,120	From St. Peter; sandstone.
Green Bay	. . . .	921			432,000	
Kenosha	Water Works Co.	1,365	$4\frac{1}{2}$	26		Cased 185 feet.
Milwaukee	Soldiers' Home	1,700				
Milwaukee	Nunnemacher Distillery	940				
Madison	Capital Park	1,015				
Milwaukee	Falk Brewing Co.	1,250				
Milwaukee	. . . .	1,018		44		From St. Peter.
Oshkosh	. . . .	500, 300, 150	2, 5 and 3			
Prairie du Chien	Mill Co.	1,012	6	28	640,000	From Potsdam.
Prairie du Chien	City	1,044	8	22	1,296,000	From Potsdam. Cased 150 feet with copper tube.
Sparta	Private	300	4			
Stoughton	. . . .	1,009				
Sheboygan	. . . .	1,475				
Tomah	. . . .	492				No flow.
Watertown	C. M. & St. P.	107		$4\frac{1}{2}$		From St. Peter; sandstone.
Waukesha	. . . .	1,500				In Potsdam.
West de Pere	. . . .			43		
Western Union Junction	C. M. & St. P.	1,263		17		From St. Peter; sandstone.
MINNESOTA.						
Mankato	City	2,200				No flow.
Minneapolis	City	900				
Mendota	Railway Co.	857		6	432,000	
Owatonna	City	387				No flow.
Red Wing	C. M. & St. P.	450		$32\frac{1}{2}$	1,152,000	Flow began at a depth of 190 feet.
St. Peter	Hospital Well	197				Flow began at a depth of 116 feet.
St. Paul	Reformed School	252				Flow from 150 feet.
West St. Paul	Private Wells	200 to 375		8 to 13		From St. Croix (Potsdam ?).

TABLE XIV.

GEOLOGICAL SECTION OF ARTESIAN AND DEEP WELLS IN THE UPPER MISSISSIPPI VALLEY, SHOWING STRATA ENCOUNTERED AND THICKNESS OF SAME AT VARIOUS LOCALITIES.

The depths are given in feet.

LOCALITIES.	Elevation of top of well above sea level.	Drift (loam, sand, gravel and clay).	Lower coal measures.	Sub-carboniferous.	Devonian.	Niagara.	Hudson River or Cincinnati shale.	TRENTON. Galena.	TRENTON. Trenton.	St. Peter's sandstone.	Lower magnesian limestone.	Potsdam sandstone.	Archean.	Total depth.
Rockford, Ill., well No. 1	713	125							30	225	105	1,035		1,530
Rockford, Ill., well No. 3	724	192								188	105	1,513		1,996
Galena, Ill.	605	65							95	145	170	1,035		1,510
Morrison, Ill.	670	110				75	295	100	200	200	120	180		1,190
Sterling, Ill.		20				30	100	550		300	500	700		2,200
Aurora, Ill.		4				196	130	340		236	160	1,480		2,440
Chicago (stock yards)						254	250	330		155	70			1,105
Joliet, Ill.						230	68	334		257	450	730		2,069
Marseilles, Ill.	478	12	73						4	11				100
Streator, Ill.		30	211					203		225	90	1,737		2,496
Peru, Ill.		60	390	50	100	214	162	376		8				1,360
Ottawa, Ill. (Court House)	486									171	139			310
Ottawa, Ill. (King Catlin and La Chapell)	486	35								130	145	1,530		1,810
Monmouth, Ill.		67	5	220	109	68	85	526		154				1,232
Rock Island, Ill.	558				60	279	180	353	90	145	811	367		2,292
Moline, Ill.		7			113	275	220	320		205	316	161		1,628
Carbon Cliff, Ill.		12			130	338	200	220						900
Warsaw, Ill.		82		183	33	80	184	239		33	10			844

TABLE XIV.—Continued.

Geological Section of Artesian and Deep Wells in the Upper Mississippi Valley, Showing Strata Encountered and Thickness of Same at Various Localities.

The depths are given in feet.

Localities.	Elevation of top of well above sea level.	Drift (loam, sand, gravel and clay).	Lower coal measures.	Sub-carboniferous.	Devonian.	Niagara.	Hudson River or Cincinnati shale.	Trenton. Galena.	Trenton. Trenton.	St. Peter's sandstone.	Lower magnesian limestone.	Potsdam Sandstone	Archean.	Total depth.
Ipava, Ill.		23	130	50	215	360	185	270		290				1,570
Palmyra, Wis.		46						130	81	93	62	338		750
Western Union Junction, Wis.		147				233	200	285		100	141	157		1,263
Racine, Wis.		115				305	185	283		48	100	204		1,240
Milwaukee, Wis.		170				267	165	253		193				1,048
Sheboygan, Wis.		92				719	240	213		212				1,475
Janesville, Wis.		350										683		1,033
Oshkosh, Wis.		60								240 (a)		414	248	961
Sparta, Wis.												300		300
Oil City, Wis.		42										448	20	510
Tomah, Wis.		25										427	40	492
La Crosse, Wis.		170										403		573
Prairie du Chien, Wis.		147										812		959
Fond du Lac, Wis.		95						195		135				425
St. Paul, Minn. (Reform School)		36½					24 (?)	114		77½				252
Mankato, Minn.		290									205	1,705		2,200
Owatonna, Minn.		39	59 (b)				20 (b)	144	28	97				387
Minneapolis, Minn.		42							28	164	102	1,085		1,421
Red Wing, Minn.		40										410		450
Saint Peter, Minn.		15										182		197
Mendota, Minn.		22								60	30	745		857

(a) Saint Peter, sandstone wanting. (b) Cretaceous,

Many of the other deposits of this area may be made available as sources of water supply by driving through them infiltration tunnels of sufficient extent to allow the infiltration of the amount of water needed.

The surface waters offer obvious sources of supply, which need only protection from organic contamination. The larger streams are the more liable to contamination and more difficult to protect; hence it will often be advisable to impound the surface waters of small drainage areas which may be more easily protected. Table XV contains data respecting the geological sources of most of the water supplies of cities of over 5,000 inhabitants in the Upper Mississippi and Western Lake Michigan valleys, and shows the extent to which these sources are at present utilized.

QUALITY OF WATER.

The quality of a water is as important as its quantity, and should be carefully considered.

The sanitary character of a surface water, and to a less extent that of a ground water, is dependent upon the character of its watershed and is subject to radical changes, as the population within its boundaries varies in number, in character and in occupation. The effect of this variation upon the character of the water supplied may by proper sanitary regulations be somewhat modified; but it can never be entirely prevented. A drainage valley is the natural, and usually the only, practical means for the disposal of drainage waters, and the soluble matter deposited on its area will to some extent find its way into those waters in spite of all precautions. The extent of the influence of organic contamination is about proportional to the density of population and inversely to the size of the stream which receives its drainage. Waters once receiving organic matters retain them indefinitely, for, although the degree of contamination may be lessened by dilution, deposition and bacteriological agencies, there is not a river long enough to purify itself entirely during its flow from source to sea, when once thoroughly contaminated. Nothing but clarification will make such waters safe for domestic use, and the difficulties encountered in the different methods of effecting this leave it very doubtful whether anything short of distillation is entirely effective under all circumstances.

TABLE XV.—SOURCE OF WATER SUPPLY OF CITIES AND TOWNS OF 5,000 OR MORE INHABITANTS IN THE UPPER MISSISSIPPI AND WESTERN LAKE MICHIGAN VALLEYS, UPPER MISSISSIPPI VALLEY.

WISCONSIN.

City.	County.	Population, 1890.	Elevation above sea level at R. R. Depot. Railway.	Elevation.	Source of supply.	Geological source.	Remarks.
Beloit	Rock	6,315	C. & N. W.	741 feet.	Large well.	Trenton limestone.	500,000 gallons per day; diameter, 30 feet; depth, 40 feet.
Chippewa Falls	Chippewa	8,670	C. St. P. M. & O.	861 "	Chippewa River.	Surface.	Filtered.
Eau Claire	Eau Claire	17,415	C. St. P. M. & O.	839 "	Wheaton Springs.	Potsdam (?).	
Janesville	Rock	10,836			Artesian well.	Potsdam.	Flowing well, 8 feet diameter, 1,087 feet deep.
			C. M. & St. P.	657 "			
La Crosse	La Crosse	25,090	L. W. Mississippi.	628 "	Mississippi River.	Surface.	
Madison	Lane	13,426	C. M. & St. P.	857 "	8 Artesian wells.	Potsdam.	Direct section.
Menomonie	Dunn	5,491	C. M. & St. P.	805 "	Springs and Red Cedar River.	Surface.	
Merrill	Lincoln	6,809			Prairie River.	Surface.	
Portage	Columbia	5,143	C. M. & St. P.	813 "	Wisconsin River.	Surface.	Filtered.
Stevens Point	Portage	7,896	W. C. Ry.	1,090 "	Wisconsin River.	Surface.	Filtered.
Watertown	Jefferson	8,755			No system.		
Waukesha	Waukesha	6,321	C. & N. W.	818 "	1 artesian well. 2 large wells.	Potsdam.	Diameter, 40 feet; depth, 26 feet. " 55 feet; " 26 feet. Artesian, 1,500 feet deep.
Wausaw	Marathon	9,253	C. M. & St. P.	1,224 "	Large well.	Drift. (?)	Diameter, 40 feet; depth. 37 feet.

ILLINOIS.

City.	County.	Population, 1890.	Railway.	Elevation.	Source of supply.	Geological source.	Remarks.
Alton	Madison	10,294	C. & A.	470 feet.	Mississippi River.	Surface.	Filtered.
Aurora	Kane	19,688	C. B. & Q.	649 "	2 artesian wells, Fox River.	Potsdam.	Diameter. Depth. 8 inches to 6 inches. 1,388 feet. 15 " to 5 " 2,440 "
Bloomington	McLean	20,484	I. C.	827 "	Large well, drive wells.	Drift.	
Canton	Fulton	5,604	C. B. & Q.	651 "	Artesian well.	Potsdam (?).	2,500 feet deep.
Decatur	Macon	16,841	I. C.	670 "	Sangamon River.	Surface.	
Dixon	Lee	5,161	C. & N. W.	725 "	Artesian wells.	Potsdam.	
Elgin	Kane	17,823	C. M. & St. P.	713 "	Fox River.	Surface.	
Freeport	Stephenson	10,189	C. & N. W.	757 "	18 drive wells.	Drift.	
Galena	Jo Davies	5,635	C. & N. W,	606 "	Artesian well.	Potsdam.	
Galesburg	Knox	15,264	C. B. & Q.	782 "	Drive wells.	Drift.	
Jacksonville	Morgan	12,935	J. S. E.	619 "	Mining shaft. Artesian well. Surface water.	Surface and coal measures.	

Joliet	Will	23,264	C. S. F. & C.	537 feet.	Drive wells. 2 artesian wells.	Drift & St. Peter's.	Depth, 1,196 and 1,203 feet.
Kankakee	Kankakee	9,025	K. & S.	626 "	Kankakee River.	Surface.	
La Salle	La Salle	9,855	I. C.	514 "	Artesian wells.	Potsdam.	
Lemont	Cook	6,000	C. S. F. & C.	596 "	Artesian wells.	St. Peter.	
Lincoln	Logan	6,725	C. & A.	612 "	12 drive wells. 2 large wells.	Drift.	Diameter, 4 inches; 25 to 40 feet deep. " 30 feet 25 feet deep.
Moline	Rock Island	12,000	C. R. I. & P.	773 "	Mississippi River.	Surface.	
Monmouth	Warren	5,936	C. B. & Q.	774 "	Artesian wells.	St. Peter.	6-inch and 4-inch diameter; 1,227 feet deep.
Ottawa	La Salle	9,985	C. B. & Q.	484 "	Artesian wells.	Potsdam.	350 feet deep.
Pana	Christian	5,077					
Pekin	Tazewell	6,347	C. S. F. & C.	476 "	Drive wells.	Fluvial drift.	
Peoria	Peoria	41,024	C. B. & Q.	452 "	Large well.	Fluvial drift.	Gravel in bed of Illinois River.
Peru	La Salle	5,550	C. R. I. & P.	669 "	Artesian well.	Potsdam.	
Quincy	Adams	31,494	C. B. & Q.	485 "	Mississippi River. 5 artesian wells.	Surface. Potsdam.	
Rockford	Winnebago	23,584	C. & N. W.	730 "	4 artesian wells.	St. Peter.	
Rock Island	Rock Island	13,634	R. I. & P.	470 "	Mississippi River.	Surface.	
Springfield	Sangamon	24,963	I. C.	602 "	Well and filter galleries.	Drift.	
Sterling	Whiteside	5,824	C. & N. W.	645 "	Rock River and artesian well.	Surface. Potsdam.	8-inch to 6-inch diameter.
Streator	La Salle	11,414	C. B. & Q.	622 "	Vermillion River.	Surface.	

IOWA.

Boone	Boone	6,520	C. & N. W. Union Depot.	1,143 feet. 533 "	Aretsian wells.	St. Peter. (?)	
Burlington	Des Moines	22 565	Low water	511 "	Mississippi River.	Surface.	
Cedar Rapids	Linn	18,020	C. & N. W.	733 "	Cedar River, 5 artesian wells.	Surface & Potsdam.	1,425 and 2,225 feet deep.
Clinton	Clinton	13,619	C. & N. W. Low water	593 " 566 "	3 artesian wells.	Potsdam and St. Peter.	
Davenport	Scott	26,872	C. R. I. & P.	595 "	Mississippi River.	Surface.	
Des Moines	Polk	50,093	C. R. I. & P.	805 "	Large well.	Drift.	
Dubuque	Dubuque	30,311	C. St. P. & K. C. Low water.	611 " 585 "	Artesian wells.	Potsdam.	
Fort Madison	Lee	7,901	C. S. F. & C. Low water.	522 " 502 "	Mississippi River.	Surface.	
Keokuk	Lee	14,101	C. B. & Q. Low water.	493 " 477 "	Mississippi River.	Surface.	
Lyons	Clinton	5,799			Mississippi River.	Surface.	
Marshalltown	Marshall	8,911			Iowa River.	Surface.	
Muscatine	Muscatine	11,511	C. R. I. & P. Low water.	562 " 531 "	Mississippi River.	Surface.	
Oskaloosa	Mahaska	6,558	C. R. I. & P.	843 "	Surface water.	Surface.	
Ottumwa	Wapello	11,001	C. B. & Q.	649 "	Des Moines River.	Surface.	
Waterloo	Black Hawk	6,674	I. C.	856 "	Cedar River.	Surface.	

TABLE XV.—CONTINUED.

MINNESOTA.

City.	County.	Population, 1890.	Elevation above sea level at R. R. Depot.		Source of supply.	Geological source.	Remarks.
			Railway.	Elevation.			
Brainerd	Crow Wing	5,703	N. P. R. R.	1,209 feet.	Mississippi River.	Surface.	
Faribault	Rice	6,520	C. M. & St. P.	1,003 "	Surface wells.	Drift.	
Mankato	Blue Earth	8,838	C. M. & St. P.	778 "	Artesian well.	Potsdam.	2,200 feet deep; flowing.
Minneapolis	Hennepin	164,738	Union.	810 "	Mississippi River.	Surface.	
Red Wing	Goodhue	6,294	C. M. & St. P.	670 "	Mississippi River.	Surface.	Filtered.
Rochester	Olmsted	5,321	C. & N. W.	983 "	Springs and creek.	Surface.	
St. Cloud	Stearns	7,686	St. P. M. & N.	1,037 "	Mississippi River.	Surface.	
St. Paul	Ramsey	133,156	Union.	703 "	Lakes, Phalen, Vaduais, etc.	Surface.	Chain of 19 lakes.
Stillwater	Washington	11,260	C. St. P. M. & O.	680 "	Lake McKusick.	Surface.	Filtered.
Winona	Winona	18,208	C. M. & St. P.	660 "	2 wells.	Alluvial drift.	Diameter, 38 feet; depth, 50 feet.
MISSOURI.							
Hannibal	Marion	12,857	Union.	472 feet.	Mississippi River.	Surface.	
Loisiana	Pike	5,090	C. & A.	487 "	Mississippi River.	Surface.	
WESTERN LAKE MICHIGAN VALLEY, WISCONSIN.							
Appleton	Ontagamie	11,869	M. & N.	723 feet.	Fox River and 3 artesian wells.	Surface & Potsdam.	Diameter, 6 feet; depth, 430 feet.
Fond du Lac	Fond du Lac	12,024	C. & N. W.	770 "	4 artesian wells.	St. Peter.	600 feet deep.
Green Bay	Brown	9,069	M. & N.	589 "	Artesian wells.	St. Peter.	6-inch diameter; 921 feet deep.
Kenosha	Kenosha	6,532	C. & N. W.	611 "	4 artesian wells.	St. Peter.	4½-inch diameter; 1,365 feet deep.
Manitowoc	Manitowoc	7,710	M. L. S. & W.	593 "	Lake Michigan.	Surface.	Through filter galleries.
Marinette	Marinette	11,523	C. & N. W.	594 "	Green Bay.	Surface.	
Milwaukee	Milwaukee	204,468	Lake Michigan.	581 "	Lake Michigan.	Surface.	
Neenah	Winnebago	5,083	M. & N.	752 "			No system.
Oconto	Oconto	5,219	C. & N. W.	590 "	Oconto River.	Surface.	
Oshkosh	Winnebago	22,836	M. L. S. & W.	744 "	Lake Winnebago and artesian wells.	Surface & Potsdam.	500 feet deep.
Racine	Racine	21,014	C. & N. W.	629 "	Lake Michigan.	Surface.	
Sheboygan	Sheboygan	16,359	C. & N. W.	588 "	Lake Michigan.	Surface.	
ILLINOIS.							
Evanston	Cook	12,762	C. & N. W.	603 feet.	Lake Michigan.	Surface.	
Chicago	Cook	1,438,010	Lake level. I. C.	581 " 587 "	Lake Michigan.	Surface.	

TABLE XVI.

Sanitary Analyses of Lake Michigan Water and of River Waters in the Illinois River Basin.

Analyses by Prof. J. H. Long.

Quantities Given in Parts per 1,000,000.

Locality.	Season.	Mean of Several Analyses.	Total Solids.	Suspended Matter.	Nitrogen in Nitrates.	Chlorine.	Hardness, $CaCO_3$.	Free Ammonia.	Albuminoid Ammonia.	Oxygen Consumed.	Source of Supply.
Chicago	. . . .	27	149.9	13.5	0.00	2.113	125.3	.007	.089	1.42	Lake Michigan water.
Bridgeport . .	Summer . .	29	471.2	129.2	0.00	46.811	201.3	12.253	2.558	23.113	Canal (Chicago sewage).
" . .	Winter . .	9	376.6	27 2	0.00	62.934	. .	8.925	2.806	26.502	" " "
Lockport . . .	Summer . .	24	431.2	69 8	0.00	46 120	207.7	10.882	1.99	16.23	" " "
" . . .	Winter . .	8	408.6	24 6	0.00	56.083	. .	8.149	2.489	22.82	" " "
Joliet	Summer . .	26	442.7	107.9	0.00	43.658	216.8	8.932	1.681	14.301	Canal (Dam 2), below Desplaines River.
"	Winter . .	8	432.8	55.5	0.00	57.717	. .	8.488	2.666	21.717	" " " " "
Channahon . .	Summer . .	21	294.7	14.1	.307	5.786	244.8	.417	.346	4.743	Du Page River.
Wilmington . .	" . .	19	251.4	35.6	.094	1.015	164.1	.114	.585	12.661	Kankakee River.
Morris . . .	" . .	24	355.9	30.85	.367	32.149	214.8	4.107	.707	10.920	Illinois River.
"	Winter	8	325.2	29.1	0.00	28.748	. .	4.716	1.587	10.696	" "
Ottawa	Summer . .	18	330.3	46 3	.027	4.974	242.1	.278	.463	7.066	Fox River.
La Salle	" . .	7	450 6	87.8	3.348	5.461	255.8	.429	.341	6.914	Big Vermillion River.
"	" . .	7	375.1	30.8	.362	5.661	210.2	.180	.411	7.15	Little Vermillion River.
"	" . .	23	345.7	50.3	1.037	19.717	211.7	.623	.526	8 558	Illinois River.
" . . .	Winter . .	9	417.6	93 8	.942	13.105	. .	1.456	.637	8.582	" "
Henry	Summer . .	19	306.	27.5	.683	17.660	201.4	.467	.481	8.657	" "
"	Winter	5	316.	30.9	.962	11.6 1	. .	1.059	.404	8.636	" "
Peoria	Summer .	19	329.75	54.27	.8915	12.358	199.7	.210	.522	9.769	Illinois River, at former inlet to pumps.
"	" . .	14	327.7	27.4	.897	28.334	206.6	.087	.397	8.184	Illinois River, from Peoria hydrant.
Pekin	" . .	16	353.	84.3	.795	16.152	204.6	.615	.650	9.410	Illinois River.
"	Winter . .	6	352.	43.5	1.259	11.752	. .	1.591	1.015	13.358	" "
Havanna . . .	Summer . .	24	301.78	45.4	.731	11.583	201.2	.342	.430	8.142	" "
" . . .	Winter . .	9	352.4	80.8	.414	9.277	. .	1.078	.585	9.231	" "
Beardstown . .	Summer . .	24	390.	84.7	.62	7.524	201.9	.202	.380	7.354	" "
" . .	Winter .	6	317.8	56.3	.966	6.933	. .	.762	.357	5.505	" "
Grafton	Summer . .	12	301.6	50.3	.582	9.205	242.1	.095	.483	7.300	Illinois River, near mouth of river.
"	Winter .	9	410.8	44.6	.087	23.641	. .	.875	.722	9.818	" " " " "

TABLE XVII.

Sanitary Analyses of Waters of the Upper Mississippi River.

Quantities Given in Parts per 1,000,000.

Locality.	Season.	Mean of several analyses.	Total Solids.	Suspended matter.	Nitrogen in Nitrates.	Chlorine.	Hardness Ca Co_3.	Free Ammonia.	Albuminoid Ammonia.	Oxygen consumed.	Source of water.	Analyst.
Aitkin, Minn.	Fall, '86 . . .		190.		.15	2.1		.05	.44	12.04	Above city.	From analyses by Minnesota State Board of Health.
Aitkin, Minn.	" . . .				.23	2.1		.26	.22	12.28	Below city.	
Brainard, Minn.	" . . .		150.		.074	1.7		.03	.37	10.83	Below city.	
Minneapolis, Minn.	" . . .		230.		.30	1.6		.13	.135	7.31	Two miles above city.	
Minneapolis, Minn.	" . . .		210.		.17	4.7		.615	.260	8.48	Below flats.	
Fort Snelling, Minn. . .	" . . .					1.6		.08	.33	8.77		
St. Paul, Minn.	" . .		135.		.10	4.5		.44	.12	7.14	At city.	
St. Paul, Minn.	" . . .				.36	4.5		.26	.26	7.73	Below city.	
Red Wing, Minn.	" . . .				.14	3.0		.10	.24	8.16	Above city.	
Winona, Minn.	" . . .		2[illegible]0.		.074	2.2		.35	.155	8.97	Above city.	
Winona, Minn.	" . . .				.10	2.5		.025	.34	7.77	Below city.	
East Dubuque, Ill.	Summer, '88 .	3	180.7	13.3		1.397	159.	.053	.150	4.960	Mississippi River.	Prof. J. H. Long.
Rock Island, Ill.	" .	4	192.2	26.2		1.315	151.	.054	.251	6.060	Mississippi River.	Prof. J. H. Long.
Quincy, Ill.	" .	2	180.3	12.3		1.049	147	.070	.273	6.090	Mississippi River.	Prof. J. H. Long.
Alton, Ill.	" .	15	2 8.6	75.2		4.083	169.4	.166	.356	7.356	Mississippi River.	Prof. J. H. Long.
Alton, Ill.	Winter . . .	8	309.9	61.3	.317	5.834		.422	.396	7.562	Mississippi River.	Prof. J. H. Long.
Alton, Ill.	Summer . .	15	238.3	33.3		4.2[illegible]2	174.	.062	.261	6.438	Miss. River (hydrant).	Prof. J. H. Long.
St. Louis, Mo.	" . .	4	781.6	496.6		9.814	204.	.065	.197	7.066	Mississippi River.	Prof. J. H. Long.
East St. Louis, Ill.	" . .	8	314.7	95.3		4.476	186.	.046	.265	5.805	Mississippi River (2 m. from pump house.)	Prof. J. H. Long.
East St. Louis, Ill.	" . .	8	616.4	67.7		4.457	136.	.05[illegible]	.417	3.757	Miss. River (pump house)	Prof. J. H. Long.
Chester, Ill.	" . .	3	439.3	111.2		7.161	291.	.076	.236	5.520	Mississippi River.	Prof. J. H. Long.
Cairo, Ill.	" . .	3	577.7	318.3		7.648	196.	.088	.397	8.426	Mississippi River.	Prof. J. H. Long.

TABLE XVIII.

Sanitary Analyses of Various River Waters in the Upper Mississippi Valley.

Quantities Given in Parts per 1,000,000.

Locality.	Season.	No. of Analyses.	Total Solids.	Suspended Matter.	Nitrogen as Nitrates.	Chlorine.	Hardness Ca Co_3.	Free Ammonia.	Albuminoid Ammonia.	Oxygen consumed.	Source of water.	Analyst.
St. Cloud, Minn.	Fall, '86					12.0		.04	.94	9.00	Creek above water works sediment.	Analyses by Minnesota State Board of Health.
Stillwater, Minn.	"		160.		.01	1.5		.025	.13	6.04	St. Croix River, ¼ m. above city.	
Stillwater, Minn.	"				.01	1.1		.05	.14	7.70	St. Croix River, 1 m. below city.	
Mankato, Minn.	"		450.			2.0		.14	.17	3.32	Blue Earth River.	
Mankato, Minn.	"		450.			2.5				4.80	Minnesota R., above city.	
Mankato, Minn.	"					8.0		.59	.35	6.09	Minnesota R., below city.	
Fort Snelling, Minn.	"				.15	1.18		.015	.26	3.27	Minnesota River.	
Elgin, Ill.	Fall, '87		196.		.00	6.0	85.	.001	.01		Fox R., opposite pumping station.	Prof. Kedzie.
Cairo, Ill.	Summer	3	208.1	116.9	0.00	3.104	46.	.083	.184	4.533	Ohio River, unfiltered.	Prof. J. H. Long.
Cairo, Ill.	"	2	737.4	5.9	0.00	3.069	85.	.061	.078	2.965	Ohio River, filtered.	Prof. J. H. Long.
Cairo, Ill.	"	3	154.6	2.7	0.00	2.823	78.	.096	.088	2.516	Ohio River, filtered and aërated.	Prof. J. H. Long.
Aurora, Ill.	"	1	302.5	3.4		2.449	261.	.066	.189	3.980	Fox River.	Prof. J. H. Long.
Elgin, Ill.	"	3	266.5	2.0		3.232	282.	.265	.275	4.000	Fox River, filtered.	Prof. J. H. Long.
Belleville, Ill.	"	11	136.0	19.4		4.248	80.	.070	.516	7.600	Richland Creek, reservoir.	Prof. J. H. Long.
Belleville, Ill.	"		149.1	5.8		1.775	125.	.160	.354	5.610	Richland Creek, filtered.	Prof. J. H. Long.
Danville, Ill.	"	4	337.1	11.0		2.960	289.	.060	.159	3.430	Vermillion R., unfiltered.	Prof. J. H. Long.
Springfield, Ill.	"	1	295.8	11.8	Trace.	7.080	250.	.113	.208	3.360	Sangamon R., unfiltered.	Prof. J. H. Long.
Rockford, Ill.	"	3	278.91		0.7	2.3		.04	.18	1.8	Rock River.	Prof. E. G. Smith.
Lincoln, Ill.	"	3	325.9	10.9		4.941	285.	.015	.066	2.53	Small stream, filtered.	Prof. J. H. Long.

TABLE XIX.

Sanitary Analyses of Various Waters in the Upper Mississippi Valley.

Quantities Given in Parts per 1,000,000.

ARTESIAN WELLS.

Locality.	Season.	Number of Analyses.	Total Solids.	Suspended Matter.	Nitrogen in Nitrates.	Chlorine.	Hardness, $CaCO_3$.	Free Ammonia.	Albuminoid Ammonia.	Oxygen Consumed.	Source of Supply.	Analyst.
State Prison, Joliet, Ill.	Summer	3	766.9	1.76	. .	199.80	242.0	5.616	.526	2.560	2 artesian wells, 553 and 1948 feet deep.	J. H. Long.
Joliet, Ill.	"	4	453.1	7.4	.541	8.337	326.6	.032	.080	2.373	3 artesian wells, 1200 feet deep.	"
Galena, Ill.	"	4	286.1	2.6	. .	.605	201.	.075	.061	2.140	Artesian well, 1507 feet deep.	"
Ottawa, Ill.	"	. .	426.0	. .	.28	12.78	. .	.680	.030	.800	Artesian well, Potsdam.	"
Rockford, Ill.	"		291.0	0.0	0.00	2.4	278.6	.01	.01	1.400	Artesian wells, Potsdam.	E. G. Smith.
Rockford, Ill.	"	. .	. . .	. .	0.00	1.88	. .	.00	.00	0.6	Artesian wells, St. Peter.	
Belvidere, Ill.	"	. .	327.2	0.0	.22	. . .	157.	.365	.400	4.000	Artesian wells.	
Princeton, Ill.	"		407.	0.0	0.00	3.20	271.1	.003	.00	.012	" "	E. H. Bartley.
La Grange, Ill.	"	. .	540.	0.0	0.00	41.06	300.0	.400	.050	1.900	" "	E. G. Smith.
Aurora, Ill.	. . . . .	. .	1032.	. .	.43	277.03	. .	.514	.084	.480	" "	J. H. Long.
Red Wing, Minn.	Fall, '86	. .	390.	. .	. .	85.0	. .	.195	.02	0.00	Artesian well at railway station.	State Board of Health.
Red Wing, Minn.	"	. .	380.	. .	20.42	36.0	.	.095	.015	.29	" " " "	" " "
Beardstown, Ill.	July, '88	. .	6480.3	10.0	. .	3405.5	302.0	2.90	.112	17360	Artesian well, St. Peter's.	Prof. J. H. Long.

SPRINGS AND ROCK WATERS.

Kankakee Insane Asylum	Summer	5	256.1	15.2	. .	2.069	223.	.037	.267	7.680	Filtering gallery cut through sand rock.	J. H. Long.
Elgin Insane Asylum	"	3	351.1	4.9	. .	3.462	300.	.022	.051	.933	Spring on the grounds.	"
Morrison	"	4	390.4	3.0	6.421	7.485	348.5	.009	.033	1.100	Large well around large spring.	"
Marseilles	"	. .	476.6	53.3	5.796	14.762	318.	.087	.172	3.200	Spring.	"
Galesburg	"	. .	142.1	11.2	.00	3.77	336.	1.801	.128	2.100	Dr. Foote's spring.	"
Bunker Hill	"	. .	701.8	3.3	.00	4.956	184.	.138	.026	1.010	Spring.	"
La Salle	"	. .	342.6	. .	1.14	2.650	316.	.111	.038	.920	East spring.	"
La Salle	"	. .	353.0	. .	.63	1.140	328.	. .	. .	3.50	West spring.	"
Stillwater, Minn.	Fall, '86	. .	160.0	. .	. .	2.0	. .	.12	.05	1.35	Spring entering lake.	State Board of Health.
Minneapolis, Minn.	"	. .	293.	. .	. .	. . .	. .	.01	.018	.018	New Inglewood Spring.	C. F. Sidener.
Elgin, Ill.	Fall, '87	. .	500.	. .	. .	11.2	155.	.005	.01	. .	Kimball Spring.	
Streator, Ill.	. . . .	. .	. . .	. .	.37	7.0	29.00	.06	.08	. .	Springs, public supply.	
Chicago	. . . .	. .	. . .	. .	.063	. . .	. .	. .	.014	. .	Hampden Hotel well, 300 feet in Niagara limestone.	C. G. Wheeler.

DRIFT WATERS.

Reform School, Pontiac	Summer	3	1673.7	10.6	. .	520.06	522.	.254	.078	2.10	Well, 24 feet deep, sunk through sandy loam and sand.	J. H. Long.
Normal Soldiers' Orphans' Home	Winter	3	120.2	13.86	2.186	2.226	. .	1.060	.114	2.61	Well on grounds, 105 feet deep.	"
Freeport	Summer	4	175.5	1.7	6.266	12.890	435.	.031	.060	2.866	18 drive wells, 44 feet deep.	"
Pekin	"	4	311.8	6.5	3.834	2.854	277.8	.009	.034	.59	Drive wells, 75 feet deep.	"
Bloomington	"	4	603.6	3.5	. .	1.219	489.	.933	.082	1.820	Well, 40 feet diameter; 28 feet deep; with seven 8 inch pipes around to depth of 62 feet.	"
Cairo	"	. .	662.2	65.5	.00	3.640	558.	1.084	.102	1.800	Driven well.	"
Dwight	"	. .	. . .	. .	.82	. . .	. .	2.50	.135	5.8	Well, 200 feet deep.	A. W. Palmer.
Macomb	. . . .	. .	. .	. .	.49	.46	. .	.290	.022	. .	Ground water in sand below clay.	"
Winona, Minn.	Fall, '86	. .	340.	. .	. .	23.0	. .	.23	.02	1.20	Water-works well.	Board of Health.
Urbana, Ill.	. . . .	. .	253.67	. .	. .	11.36	9.1	1.48	.288	1.41	Water-works well, 130 feet deep.	

SURFACE WATERS.

Chicago, Ill.	. . . .	27	149.9	13.5	0.00	2.113	125.3	.007	.089	1.42	Lake Michigan water.	
Anna Insane Asylum	Summer	3	177.1	2.4	.	4.878	131.	.161	.132	2.45	Surface water.	J. H. Long.
Jacksonville	"	. .	197.0	2.1	Trace.	5.510	160.	.128	.121	6.80	Surface water collected in ravine.	"
Stillwater, Minn.	Fall, '86			. .	.05	1.0	. .	.02	.175	3.17	Lake.	State Board of Health.
St. Paul, Minn. . .	"		140.	. .	?	.75	. .	.02	.06	3.36	Lake Phalen.	" " "
St. Paul, Minn. . .	"	.	95.	. .	?	.75	. .	.33	.12	4.32	Lake.	" " "
Winona, Minn.	"	. .	. .	.	.17	2.1		.04	.52	8.09	Lake Winona.	" " "
Elgin, Ill.	Fall, '87	.	321.	. .	Trace.	5.0	160.	.00	.01	. .	Stream in Trout Park.	Prof. Kedzie.

TABLE XX.

ANALYSES OF GEOLOGICAL DEPOSITS IN UPPER MISSISSIPPI VALLEY SHOWING THE SOURCES OF THE MINERAL MATTER CONTAINED IN WATER FROM DIFFERENT SOURCES.

In Grains per United States Gallon of 231 Cubic Inches.

	Calcium Carbonate.	Magnesium Carbonate.	Silica.	Alumina.	Ferric Oxide.	Water.	Lime.	Magnesia.	Soda.	Potassa.	Organic matter.	Miscellaneous.	Total.
Peaty soil, Wisconsin	. .	. .	64.49	4.80	5.74	. .	1.62	.72	.51	.14	21.40	.58	100.00
Prairie loam, South Wisconsin	. .	. .	79.59	1.17	8.16	. .	1.30	1.04	.49	.19	1.24	.79	100.00
Red marley clay, Kewanee County, Wis.	. .	. .	60.26	13.44	4.39	. .	5.03	3.48	.15	. .	5.84	7.11	100.00
Marl, Kewanee County, Wis.	86.06	7.18	1.48	.19		1.67	. .	. .	. .	. .	2.95	.44	100.00
Locustine clay, Ashland, Wis.	4.31	4.01	58.09	25.32	4.44	4.09	. .	. .	. .	. .	. .	. .	100.26
Kaolin from Wisconsin	. .	. .	70.82	18.98	1.24	5.45	.24	.02	10	2.49	. .	.02	99.36
Drift clay, Bloomington, Ill.	3.90	5.32	67.80	11.55	4.31	2.00	. .	. .	2.42		. .	. .	97.30
Carboniferous shale, Rock Island, Ill.	.24	.75	60.61	22.81	6,10	5.00	. .	. .	. .	. .	. .	3.85	99.42
Carboniferous shale, Galesburg, Ill.	. .	. .	68.69	17.95	7.25	. .	.76	1.47	2.83	2.83	. .	1,05	100.00
Subcarboniferous limestone, Quincy, Ill.	94.68	4.31	.05	.20		.76	. .	. .	. .	. .	. .	. .	100.00
Devonian (Lower Helderberg), Milwaukee, Wis.	54.57	43.41	1.49	.21		.32	. .	. .	. .	. .	. .	. .	100.00
Niagara limestone, Racine, Wis.	52.16	45.50	. .	.82		.67	. .	. .	. .	. .	. .	.28	99.65
Niagara limestone, Chicago, Ill.	46.90	14.19	26.08	. .	6.57	6.26	. .	. .	. .	. .	. .	. .	100.00
Hudson River shale, Clinton, Ia.	. .	. .	75.50	13.04	4.00	3.00	.50	. .	. .	4.50	. .	. .	100.90
Trenton limestone, Beloit, Wis.	52.63	36.40	1,96	3.27		. .	. .	. .	. .	. .	. .	5.74	100.00
Trenton (Galena limestone), Watertown, Wis.	54.05	44.14	1.57	.07	.17	. .	. .	. .	. .	. .	. .	. .	100.00
St. Peter's sandstone, Mineral Point, Wis.	. .	. .	96.74	.71	1.45	. .	.63	.08	. .	. .	. .	. .	99.61
Lower magnesium limestone, Ripon, Wis.	51.68	40.93	3.16	3.09	.60	.70	. .	. .	. .	. .	. .	. .	100.16
Lower magnesium limestone, Utica, Ill.	43.50	30.07	1.00	20.00	2.00	3.00	. .	. .	. .	.18	. .	. .	99.75
Lake Superior sandstone, Bass Island, Wis.	. .	. .	87.02	7.17	3.91	. .	.11	1.06	.22	1.43	. .	. .	99.92
Potsdam (Mendote limestone), Greenbush, Wis.	55.68	36.52	4.18	2.17	1.45	.52	. .	. .	. .	. .	. .	. .	100.58
Potsdam (Quartzite), Minnesota	. .	. .	84.52	12.33	2.12	2.31	.31	. .	1.34	1.11	. .	. .	102.04
Potsdam sandstone, Minnesota	. .	. .	78.24	10.88	3.83	. .	.95	1.60	.06	1.67	. .	. .	97.23
Archean (Quartz diorite), Wisconsin	. .	. .	46.31	11.14	21.69	4.44	9.68	. .	6.91	. .	. .	. .	100,77
Archean (Serpentine), Wisconsin	. .	. .	38.24	1.48	. .	9.53	1.42	14.83	. .	. .	. .	34.50(a)	100.00
Archean (Syenite), Minnesota	. .	. .	65.12	16,96	4.69	. .	4.17	1.99	3.07	2.18	. .	. .	98.78
Archean (Labradorite), Minnesota	. .	. .	48.32	35.95	. .	. .	12.05	.25	2.98	.19	. .	. .	98.74

(a) Oxide of iron with a little soda.

TABLE XXI.

Analyses of Mineral Residue of Waters from the Potsdam Strata at Various Places in the Upper Mississippi Valley.

In Grains per United States Gallon of 231 Cubic Inches.

Compound.	Symbol.	Rockford, Ill., Water Works Well.	Dixon, Ill., Condensed Milk Co.'s Well.	Sterling, Ill., Water Works Co.'s Well.	Galena, Ill., Water Works Well.	Oak Park, Ill., Water Works Well.	Clinton, Iowa, Water Works Well.	Kenosha, Wis., Water Works Well.	St. Louis, Mo., Asylum Well.	Turner, Ill., R. R. Co.'s Well.	Janesville, Wis., Water Works Well.	Madison, Wis., Water Works Well.	Prairie du Chien, Wis., Water Works Well.	Sparta, Wis., Private Well.	Watertown, Wis., Water Works Well.
Potassium sulphate	K_2SO_4	.501	.07	.46	.06	6.79	. .	Trace	KBr 3.0582	4.49	.116	.24	. .	. .	.11
Sodium sulphate	Na_2SO_4	.355	.75	.51	. .		6.626	5.48	. .		.408	.29	12.798	. .	. .
Potassium chloride	K Cl	. .	. .	. .	. .	30.54	. .	. .	.8680	1.48	. .	. .	3.806	$CaCl_2$ .583	. .
Sodium chloride	Na Cl	.274	.27	.69	.10		6.662	.86	401.5730		.489	.29	90.201	.583	.86
Sodium phosphate	Na_3PO_4	Trace	Trace	Trace	. .	. .	. .	Trace	. .	. .	Trace	Trace	Trace	. .	Trace
Sodium bicarbonate	$Na_2O_2CO_2H_2O$	.816	. .	. .	. .	Na_2CO_3 8.70	6.282	. .	. .	. .	. .	1.09	NaBr .128	. .	. .
Magnesium chloride	Mg Cl_2	. .	. .	. .	. .	. .	. .	. .	46.0810	. .	. .	. .	. .	$MgSO_4$ 2.333	.45
Magnesium bicarbonate	$MgO_2CO_2H_2O$	12.798	12.16	13.35	8.50	. .	7.426	8.06	. .	. .	12.664	12.89	. .	.583	11.58
Magnesium carbonate	$MgCO_3$	. .	. .	. .	. .	2.33	. .	. .	.	4 08					
Calcium bicarbonate	$CaO_2CO_2H_2O$	13 173	14.04	14.85	3.70	. .	11.220	15.03	$CaCl_2$ 47.4911	. .	12.045	15.24	10.974	4.086	14.57
Calcium carbonate	Ca CO_3	. .	. .	. .	. .	8.16	. .	. .	. .	6.67	. .	. .	. .	. .	. .
Calcium sulphate	Ca SO_4	. .	.17	. .	. .	Trace	. .	6.02	50.1847	.11			6.22		
									Fe_2O_3		.314	. .	15.370	. .	.53
Ferrous bicarbonate	$FeO_2CO_2H_2O$	.079	.07	.06	.01	Trace	.017	.09	.0584	.12	.087	.21	.232	.583	.16
Alumina	Al_2O_3	.139	.09	.06	.06	. .		.03	. .		.093	Trace	.061	. .	.01
Silica	Si O_2	.583	.77	.61	.06	.40	6.12	.45	.9346	.56	.536		2.843	.583	.17
Total		(1) 28,718	(1) 28.39	(1) 30.64	(2)	(3) 55.89	(1) 38.854	(1) 36.02	(4) 550.2551	18.22	(1) 26.752	(5) 30.76	(6) 137.035	(6) 9.311	(1) 28.80
Depth of well in feet		1530	1500	1450	1509	2180	1674	1365	2199	2087		1015	1011	300	957

(1) Analyzed by E. G. Smith.
(2) " " W. Simpson.
(3) Analyzed by G. M. Davidson.
(4) " " Prof. P. Schweitzer.
(5) Analyzed by W. W. Daniels.
(6) " " G. Bode.

TABLE XXII.

Analyses of Mineral Residue of Waters from the St. Peter Sandstone at Various Places in the Upper Mississippi Valley.

In Grains per United States Gallon of 231 Cubic Inches.

Compound.	Symbol.	Whitewater, Wis. Blackman's Well.	Davenport, Iowa. Glucose Well.	Jerseyville, Ill. Water Works Well.	Monmouth, Ill. Water Works Well.	De Kalb, Ill. Water Works Well.	Rockford, Ill. Water Works Well.	Peru, Ill. Zinc Works Well.	Rock Island, Ill. Wagner's Brewery Well.	Burlington, Wis. Water Works Well.	Milwaukee, Wis. W. A. Jacobs' Well.	Fond du Lac, Wis. Wild's Well.	Broadhead, Wis. Gomber's Well.	Sheboygan, Wis. Public Well.	Moline, Ill. Wheelock's Well.
Potassium sulphate	K_2SO_4	.13		10.30	4.86	} 1.13	.233	. .	. .	.56	. . . .	. . .	. .	. . .	. .
Sodium sulphate	Na_2SO_4	.16	16.096	5.05	23.45		.349	7.25	15.00	1.08	8.8572	4.086	.17	. . . .	20.848
Potassium chloride	KCl	. .	. . .	. . .	. .	} .11	. . .	. .	. .	. .	.2745	. . .	. .	14.4822	.
Sodium chloride	$NaCl$	.11	28.080	85.93	9.61		.110	16.00	32.00	.46	.6405	4.086	.32	306.9436	27.854
Sodium phosphate	Na_3PO_4	Trace	. . .	Trace	. .	. .	.072	Trace	. .	Trace	. . . .	. . .	. .	. . . .	. . .
Sodium carbonate	$NaO_2CO_2H_2O$	.73	. .	. .	. .	. .	. . .	7.02	Na_2CO_3 4.00	. .	. . . .	. . .	.03	. . . .	. . .
Magnesium bicarbonate	$MgO_2CO_2H_2O$	11.97	4.770	15.53	14.07	6.47	12.286	7.16	. .	8.89	6.6307	4.670	4.86	.1742	. . .
Magnesium carbonate	$MgCO_3$	. .	. . .	. .	. .	. .	. . .	. .	6.30	. .	. . . .	. . .	. .	$MgCl_2$ 54.9139	5.849
Calcium carbonate	$CaCO_3$	. .	. . .	. .	. .	. .	. . .	. .	10.00	. .	. . . .	. . .	. .	$CaCl_2$ 27.8225	8.765
Calcium bicarbonate	$CaO_2CO_2H_2O$	15.92	5.132	6.84	15.82	8.39	13.837	12.65	. .	12.10	8.6925	6.421	6.66	13.6585	. . .
Calcium sulphate	$CaSO_4$	. .	5.540	16.91	4.70	. .	.195	. .	. .	2.46	14.5485	.584	. .	169.8277	. . .
Ferrous bicarbonate	$FeO_2CO_2H_2O$	.29	. . .	.11	.24	} .69	.151	.07	. .	.03	.1342	. .	.23	.5044	. . .
Alumina	Al_2O_3	13	.361	.06	.10		.069	.04	. .	.03	.1891	. . .	.13	.1783	. . .
Silica	SiO_2	.59	.216	.78	1.01	. .	.548	.79	. .	.40	2.3790	. . .	.69	.4665	.355
. . . .	. . . .	. .	. . .	. .	. .	organic	. . .	. .	. .	. .	. . . .	organic	organic	(a)	$FeCO_3$
. . . .	. . . .	. .	. .	. .	. .	.70	. .	. .	. .	. .	. . . .	.584	.18	.3318	.221
Total	. . . .	(1) 30.04	60.196	(1) 111.51	(1) 73.89	(2) 17.49	(1) 27.856	(1) 50.98	(3) 67.30	(1) 26.01	(4) 42.3162	(4) 20.431	13.27	(5) 589.2536	(6) 63.892
Depth of well in feet	. . . .	315	2101	2003	1227	800	370	1360	1068	1108	1200	. . .	30	1475	. . .

(1) Analyzed by E. G. Smith.
(2) " " G. M. Davidson.
(3) " " Wahl & Hennsoch.
(4) Analyzed by G. Bode.
(5) " " C. F. Chandler.
(6) " " W. Haines.

(a) Composed of chloride of lithium, bromide of sodium, and phosphate of lime, with traces of iodide of soda, sulphate of baryta and biborate of soda.

ANALYSES OF MINERAL RESIDUES OF ARTESIAN AND OTHER WELL WATERS OF THE UPPER MISSISSIPPI VALLEY

(Geological Source Uncertain.)

In Grains per United States Gallon of 231 Cubic Inches.

Compound.	Symbol	Waterloo, Wis., Well.	Chicago Artesian Wells. W. H. Boup & Co.	Chicago Artesian Wells. Munger's Laundry.	Chicago Artesian Wells. Auditorium.	Chicago Artesian Wells. Leland Hotel.	Galesville, Wis., Jordan's Well.	Watertown, Wis., Magnetic Well.	Manitowoc, Wis., Rahr's Well.	Sparta, Wis., Magnetic Well.	Humboldt, Minn., Artesian Well.	Bell Plaine, Ia., Artesian Well.	Story City, Ia., Watkin's Well.	Knox City, Mo., La:dreth's Well.	La Grange, Mo., Wyaconda Artesian Well.
Potassium sulphate . . .	K_2SO_4	. .	.10	Trace.	1.58	.129	. .	. .	. .	.64	. .	. .	. .	.4721	KCO_3 8.173
Potassium chloride . . .	KCl	7.348	. .	. .		. .		.	.584	$CaCl_2$ .61	15.655				
Sodium sulphate	Na_2SO_4	. .	. .	.47	36.75	. .	1.97	1.17	37.358	2.21	. .	5.207	6.745	30.8562	9.223
Sodium chloride	$NaCl$	24.319	1.88	1.82	2.33	2.514	.18	. .	$CaCl_2$ 22.182	.14	276.499	.512	. .	1.1721	320.607
Sodium phosphate . . .	Na_3PO_4	. .	Trace.	.28	Trace.	. .		. .	. .	.06	. .	. .	. .	. . .	. .
Sodium bicarbonate . .	$NaO_2CO_2H_2O$	37.498	8.36	7.03	. .	. .	.89	. .	. .	. .	. .	. .	. .	. .	.209
Sodium carbonate . .	Na_2CO_3	. .	. .	. .	. .	6.324	. .	. .	. .	.21	. .	. .	. .	. .	. .
Magnesium sulphate . .	$MgSO_4$	11.955	. .	. .	. .	. .	. .	.	48.149	. .	7.112	32.716	. .	23.5369	. .
Magnesium bicarbonate	$MgO_2CO_2H_2O$	16.387	3.47	7.45	. .	. .	8.16	7.58	. .	. .	. .	. .	. .	. . .	31.287
Magnesium carbonate .	$MgCO_3$	. .	. .	.		.249	. .	. .	. .	4.03	7.860	10.922	7.279	. . .	. .
Magnesium chloride . .	$MgCl_2$	. .	. .		11.90	. .	. .	. .	. .	. .	9.144	. .	. .	. . .	
Calcium bicarbonate . .	$CaO_2CO_2H_2O$	13.996	4.94	5.63	21.33	. .	6.50	11.08	25.100	. .	. .	. .	. .	32.6502	51.601
Calcium carbonate . . .	$CaCO_3$	$CaCl_2$ 29.976	. .	. .	. .	5.692	. .	. .	. .	.40	$CaCl_2$ 4.226	. .	11.624	. . .	. .
Calcium sulphate	$CaSO_4$	. .		-.	16.31	. .	. .	.58	57.788	.18	11.608	83.266	. .	18.4061	. .
Ferrous bicarbonate	$FeO_2CO_2H_2O$	. .	.15	.04	.13	.	2.67	Trace.	. .	. .	. .	.612	. .	2.3919	. .
Ferrous carbonate . . .	$FeCO_3$	. .	.	.		.3[illegible]4	. .	. .	. .	14.31	.108	. .	} .348	. . .	.
Alumina	Al_2O_3	. .	.10	.03	.07	. .	.68		. .	. .	.238	. .	}	.6697	.093
Silica	SiO	1.199	.75	.49	.84	1.337	.29	1.17	1.167	.28	1.215	.093	1.461	.9508	2.851
Organic		(i) 1.283	. .	. .	. .	.441	.48	. .	. .	(a) .12	. .	. .	.053	(b) 7.5586	.
Total		. .	(2) 18.99	(2) 23.23	(2) 91.24	(3) 16.990	(4) 21.82	(4) 21.58	(4) 192.628	(5) 23.223	(6) 33.665	(8) 133.227	(7) 27.510	(9) 118.6649	421.057
Depth		. .	800	. .	. .	. .	65 ft.	. .	(g) 150	. .	. .	. .	. .	. . .	(d) 840

(1) Analysis by D. M. Stanner.
(2) " E. G. Smith.
(3) " C. G. Wheeler.
(4) " G. Bode.
(5) " J. M. Hirsh.
(6) " G. A. Marnier.
(7) " F. W. Clarke.
(8) Analysis by Prof. Andrews.
(9) " Paul Schweitzer.
(10) " R. Chauvert & Bro.
(11) " Woodward & Robertson.
(12) " E. J. Gillett.
(13) " W. W. Daniels.

(a) Said to consist of barium, strontium and lithium carbonates.
(b) Free carbonic acid gas.
(c) Flow said to have begun at 700 feet (St. Peter's); lower flow probably from Potsdam.
(d) Flow probably from St. Peter's sandstone.
(e) About equal parts of sodium bromide and lithium chloride.
(f) In sand r
(g) Water fro there
(h) Water is f
(i) Chloride

TABLE XXIV.

Analyses of Mineral Residue of Various Surface and Drift Waters in the Upper Mississippi Valley.

In Grains per United States Gallon of 231 Cubic Inches.

Compound.	Symbol.	Chicago, Ill. Lake Michigan.	Woodstock, Ill. Well in Drift.	Rockford, Ill. Driven Well in Drift.	Lincoln, Ill. Filter Gallery in Drift.	Galesburg, Ill. Old Water Works Well Drift.	De Kalb, Ill. Corkin's Well in Drift.	Heron Lake, Minn.	Rock River, Minn.	Minneapolis, Minn. Mississippi River.
Potassium sulphate	K_2SO_4	.283	.308	.157	1.026	. .	4.68	.467	.192	.102
Sodium sulphate	Na_2So_4	.225	4.413	.216	. .	. .		1.079	1.493	.175
Potassium chloride	KCl	. .	. .	. .	.735	K_2CO_3 .432	2.33	. .	. .	. .
Sodium chloride	NaCl	. .	5.060	.111	2.31	.122	. .	.297	.117	.164
Sodium phosphate	Na_3PO_4	Trace	. .	Trace	. .	. .	. .	. .	. .	. .
Sodium bicarbonate	$NaO_2CO_2H_2O$	. .	5.295	4.66	. .	Na_2CO_3 1.505	. .	. .	. .	. .
Magnesium bicarbonate	$MgO_2CO_2H_2O$	. .	5.196	11.433	. .	. .	12.25	. .	. .	. .
Magnesium carbonate	$MgCO_3$	2.202	. .	. .	4.735	5.062	6.29	4.151	4.106	3.163
Calcium bicarbonate	$CaO_2CO_2H_2O$	. .	16.592	16.032	. .	. .	. .	$Ca2NO_3$ .292	. .	. .
Calcium carbonate	$CaCO_3$	1.465	. .	. .	7.307	9.692	16.66	5.990	7.933	6.395
Calcium sulphate	$CaSO_4$	.319	. .	. .	6.76	.332	7.39	2.792	.373	. .
Ferrous bicarbonate	$FeO_2CO_2H_2O$	. .	.926	.396	. .	. .	. .	. .	. .	. .
Ferrous carbonate	$FeCO_3$	.029	. .	. .	6.59	3.791	.12	.099	Fe_2O_3 .513	. .
Alumina	Al_2O_3	Trace	.184	.081					.058	.055
Silica	SiO_2	.306	.863	1.049	.710	1.125	.87	.414	1.225	.783
Total		(1) 7.829	(2) . .	(3) 29.941	(1) 16.079	(1) 22.061	. .	(4) 15.881	(4) 16.010	(5) 10.837

(1) Analyzed by J. H. Long.
(2) " " W. Haines.
(3) Analyzed by E. G. Smith.
(4) " " W. A. Noyes.
(5) Analyzed by J. A. Dodge.

TABLE XXV.

Analysis of Residues of Various Spring Waters in the Upper Mississippi Valley.

In Grains per United States Gallon of 231 Cubic Inches.

Compound.	Symbol.	Elgin, Ill., Zonian Spring	Versailles, Ill., Magnetic Spring.	Perry, Ill., Iron Spring	Schuyler County, Ill., Spring.	Cook County, Ill., Glen Flora Spring.	Cook County, Ill., Alcyone Mineral Spring.	Oregon, Ill., Ganymede Spring.	Versailles, Ill., Spring No. 1.	Spring Valley, Ill., Spring No. 1.	St. Croix, Wis., Mineral Spring.	Galesville, Wis., Arctic Spring.	Waukesha, Wis., Bethesda Spring.	Waukesha, Wis., Hygeia Spring.	Waukesha, Wis., Silurian Spring.	Woodworth, Wis., Bristol Soda Spring.	Milwaukee, Wis., Eureka Spring.	Palmyria, Wis., Zenobia Spring.	Lake Geneva, Wis., Sheridan Spring.	Owatonna, Minn., Vichy Spring.	Minnesota City, Minn., Bryan's Spring.	Minneapolis, Minn., Inglewood Spring.	Colfax, Iowa, Mineral Spring.	Eddyville, Iowa, Iowa Acid Spring.	Ottumwa, Iowa, Medical Spring.	Iowa Falls, Iowa, Siloam Spring.
Potassium sulphate	K_2SO_4				7.84		4.86	.156			(a)	.19	.46	.691						.28	.04	.17	.41	H_2SO_4 408.99	2.23	
Sodium sulphate	Na_2SO_4	1.747		.44		1.85	3.39			35.16	.524	.07	.54		.29	7.74	15.163	.40	.30	.45	.45	.49	78.86	.37	200.88	.427
Potassium carbonate	K_2CO_3		& Na_2CO_3 1.32	1.59				.903													.09					
Sodium chloride	$NaCl$	.707	Trace.			.18		.101	Trace.	34.80	.053	.76	1.16	1.892	.19	.43	195.365	.43	.31	.34	.03	.07	3.85		51.81	.075
Sodium phosphate	Na_3PO_4																									
Sodium bicarbonate	$Na_2O_2CO_2H_2O$	Na_2Co_3 .457				6.45			10.99		.790		1.26		.03	8.89	7.581	.18		Na_2CO_3 52.41						Na_2CO_3 21.500
Magnesium Sulphate	$MgSO_4$				2.98					9.12				4.035									31.87	13.86		
Magnesium bicarbonate	$MgO_2CO_2H_2O$			17.01		11.09	13.79		12.57		7.248	9.84	12.39	4.630		3.21	10.497	10.14	10.28	8.40				$MgCl_2$ .82		10.232
Magnesium carbonate	$MgCO_3$	2.497	8.95					8.595		3.40				$MgCl_2$ .210	6.83						6.08	4.69			30.80	
Calcium bicarbonate	$CaO_2CO_2H_2O$			15.89		15.57	18.69		17.43	$CaCl_2 + MgCl_2$ 33.72	11.193	13.65	17.02	19.229		4.36	23.910	12.85	12.55	16.37						18.112
Calcium carbonate	$CaCO_3$	9.568	14.60					9.200		8.96		$CaCl_2$ .05		FreeCO_2 1.432	9.93						10.62	9.79	17.51		22.26	
Calcium sulphate	$CaSO_4$		Trace.		73.94				2.08	3.84				$Mg2NO_3$ 1.622				.79	1 43			.12	13.07	44.65	38.23	
Ferrous bicarbonate	$FeO_2CO_2H_2O$			.55								.26	.04	$Fe PO_4$ .0086		.49			.11	.54				$FeSO_4$ 97.30		.070
Ferrous carbonate	$FeCO_3$	.499	.06		Pro. sulphate. 69.96	.11		.081						3.039	.13						.14	.01	.67		2.91	
Alumina	Al_2O_3	.266				.15	1.99		.73		.492	.15	.12		.59		11.080	.22	.05	.10			.29	226.41		.117
Silicia	SiO_2		1.40	(c) 2.76	1.31	.91 Organic. .10	.68 (c) 4.68	9.62	.82	Organic. .24	.265	.06	.74 Organic. 1.98	.705	.70 (b)	.80	6.998	.91	.73 Organic. .23	1.79 (c) 4.34	.95	1.22	(c) 7.18	NaSiO 15.89	7.30	.829
Total		(1) 15.740	(2) 26.33	(3) 38.24	(4) 156.03	(4) 36.41	(4) 48.08	(5) 20.024	(4) 44.62	(6) 129.24	(4) 20.565	(7) 25.03	(8) 35.71	(9) 37.5396	(10) 18.69	(2) 25.92	(11) 270.594	(11) 25.92	(11) 25.99	(12) 85.02	(13) 18.40	(13) 16.56	(14) 153.71	(15) 816.39	(10) 356.45	(11) 32.362

(1) Analyzed by J. E. Siebel.
(2) " G. A. Marnier.
(3) " Henry Egbren.
(4) " J. V. Z. Blaney.

(5) Analyzed by E. W. Hall.
(6) " H. Engeleman.
(7) " W. W. Daniels.
(8) " C. F. Chandler.

(9) Analyzed by A. W. Palmer.
(10) " W. S. Haines.
(11) " G. Bode.
(12) " Ennis Sander.

(13) Analyzed by W. M. Noyes.
(14) " G. Hinrichs.
(15) " J. H. Seibel.
(16) " James Carter.

(a) Spring comes from Potsdam strata.
(b) Contains trace of phosphate of iron and manganese.
(c) Free carbonic acid gas.
(d) Ammonia crenate.
(e) Potash and soda silicate.

The waters of this area have become greatly changed since its early settlement. The smaller streams, where the population is comparatively large, have become very greatly polluted and even the larger streams are at least open to suspicion. The effects of concentration of population and that of emptying sewage into comparatively small drainage channels, will be seen in Table XVI, which shows the sanitary analyses of the waters of the Chicago and Lake Michigan Canal. The effects of dilution, deposition and bacteriological oxidation will be understood by reference to the other analyses of the lower waters of the Illinois River shown in the same table.

The Mississippi River itself drains a large and thickly populated territory, but its volume is so great, relatively to that of the impurities discharged into it, that, except in a few places, it has not as yet become pronouncedly unfit for use. Its character at various points in the valley will be seen by reference to Table XVII.

Table XVIII gives the analyses of various other river waters in the Upper Mississippi Valley, the results showing the effects due to the varying relations between the volumes of the streams and the density of the population.

Table XIX shows the sanitary analyses of various other waters in this area. The deep waters will be seen to be the best in this regard; and this will always remain true where these waters are derived from distant watersheds and filtered often through miles of sandstone. If, on the other hand, as may sometimes be the case in limestone waters, the water is simply derived through cracks and fissures from the immediate surface water, the analysis will often show considerable pollution, for the flow through such channels will produce little or no change in the quality of the water.

The character of a water is dependent also on the character of the strata through which it flows, for it dissolves something from each mineral of these, and in amount dependent upon the length of the flow both in distance and in time, and upon the nature of its dissolved gases. With the local variation in the character of any particular stratum a corresponding variation in the local character of the waters from such stratum must be expected. Table XX gives the analyses of various strata in this area and consequently a general idea of the source and character of the mineral matter contained in the waters from the various strata. Table XXI shows analyses of the mineral residue of waters from the Potsdam deposits; Table XXII of waters from the St. Peter sandstone, and Tables XXIII, XXIV, and XXV, of waters from various other strata, all of which serve to illustrate the above statements. It should be noted how marked these variations are. The St. Peter water at Rockford, for instance, contains only 27 grains of mineral water, per

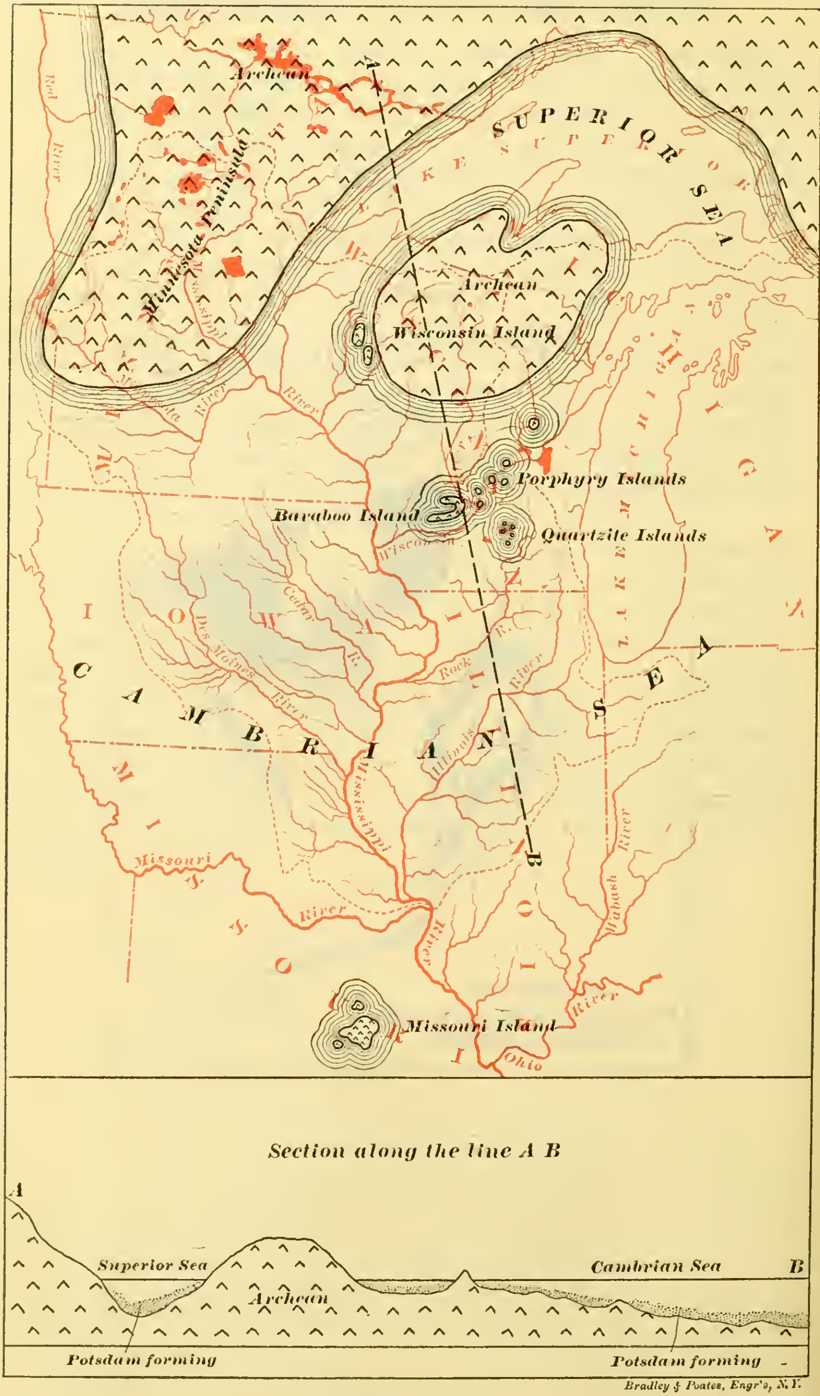
U. S. gallon, while those at Monmouth contain about 72 grains, and those at Jerseyville, 140 grains. It is also a common experience to find the various strata of a single deposit varying largely in the nature of the water they bear; tending to prove the principle that the lower waters, owing to their greater length of flow, are more highly mineralized than those of the higher strata. The Potsdam, for example, has an outcrop about 80 miles in width north and south; so that the waters of the lower stratum flow 40 to 60 miles further than those of the upper stratum. The variation in the character of a water is undoubtedly modified by transfusion of waters. Hence the most marked difference exists where the intervening strata are most impervious and homogeneous, and where transfusion is thus reduced to a minimum. A marked similarity in the character of the water at Rockford, from the Potsdam, St. Peter, and drift, will be observed. This is, no doubt, partially due to transfusion of waters, but more largely to a uniformity in the general nature of the underlying strata of this point.

It has been possible to touch but briefly on each of the various factors which influence the hydrological conditions in this territory; all of which should be studied in detail in determining the proper source of a proposed water supply. If only the superficial features of a locality be examined, we may overlook possible sources which might prove, if investigated, to be the most satisfactory and economic sources available. An examination of the geological and topographical features of the country of which the locality is a part will at least give information on which an intelligent plan may be based. If this paper affords some suggestion of the necessary extent and character of such research, its purpose is fulfilled.

Map No. 1.

APPROXIMATE MAP
OF KNOWN ARCHEAN LAND IN
NORTH AMERICA

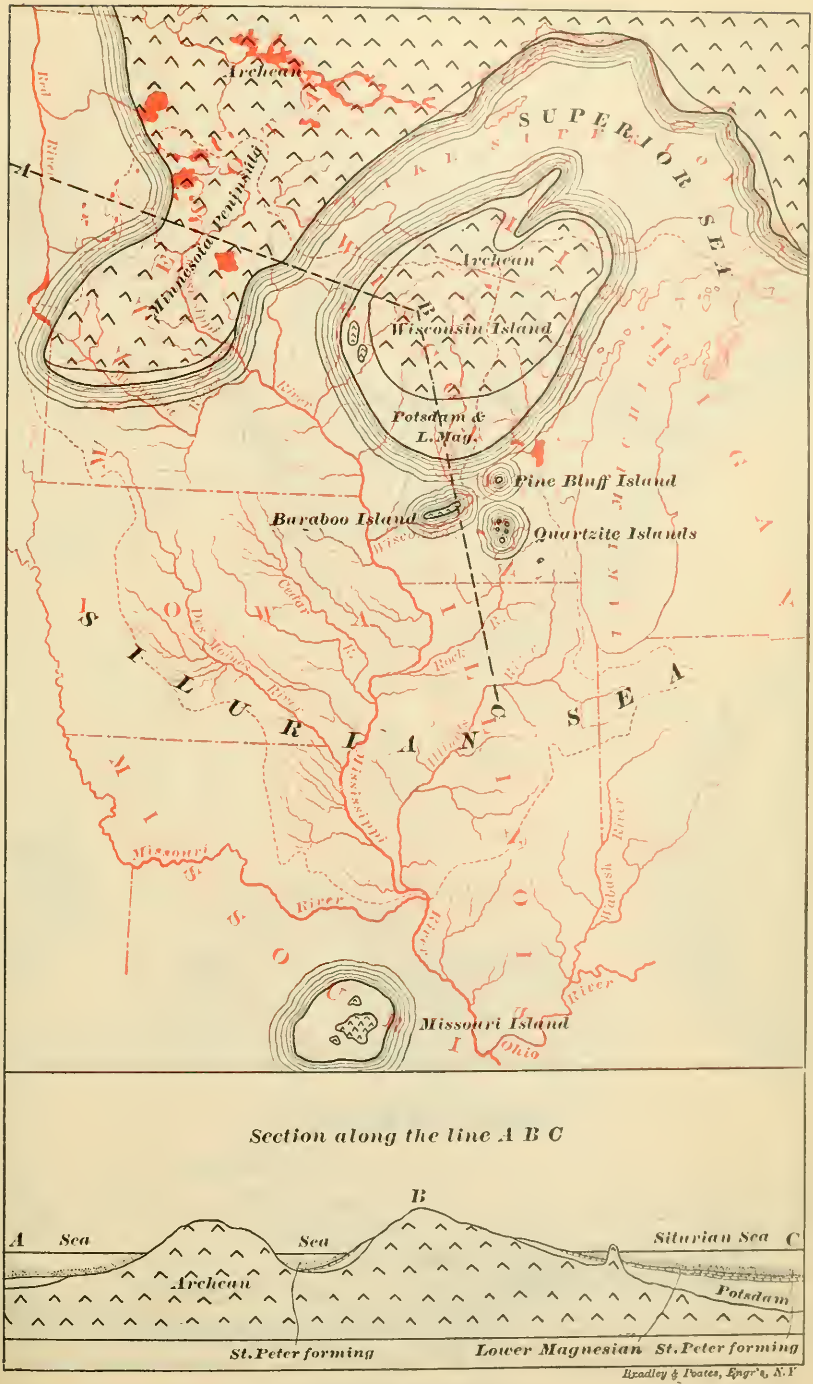
MAP NO. 2.



CAMBRIAN AGE.

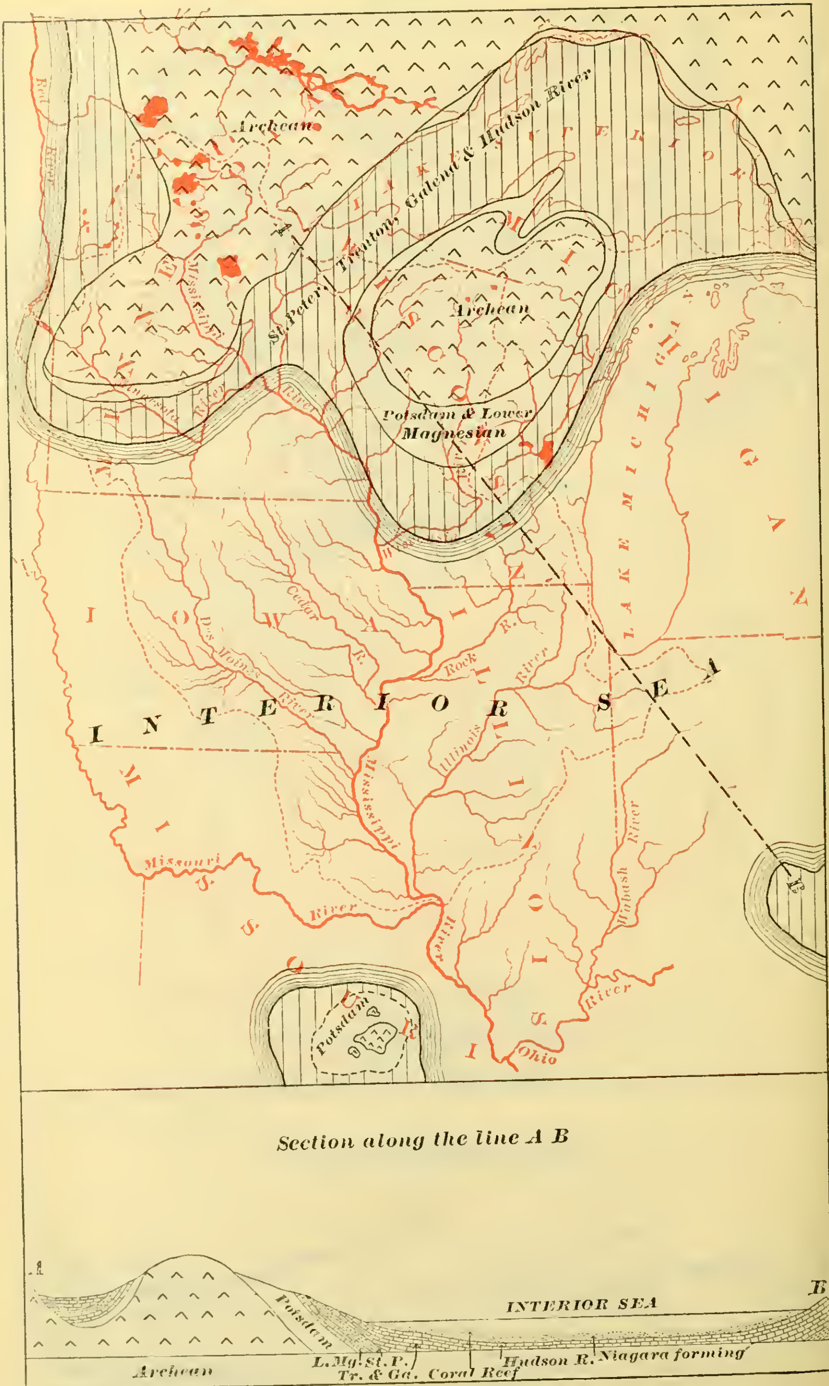
Potsdam Deposits forming in Cambrian and Superior Seas.

MAP No. 3.



BEGINNING OF SILURIAN AGE.
St. Peter Sandstone forming in the sea.

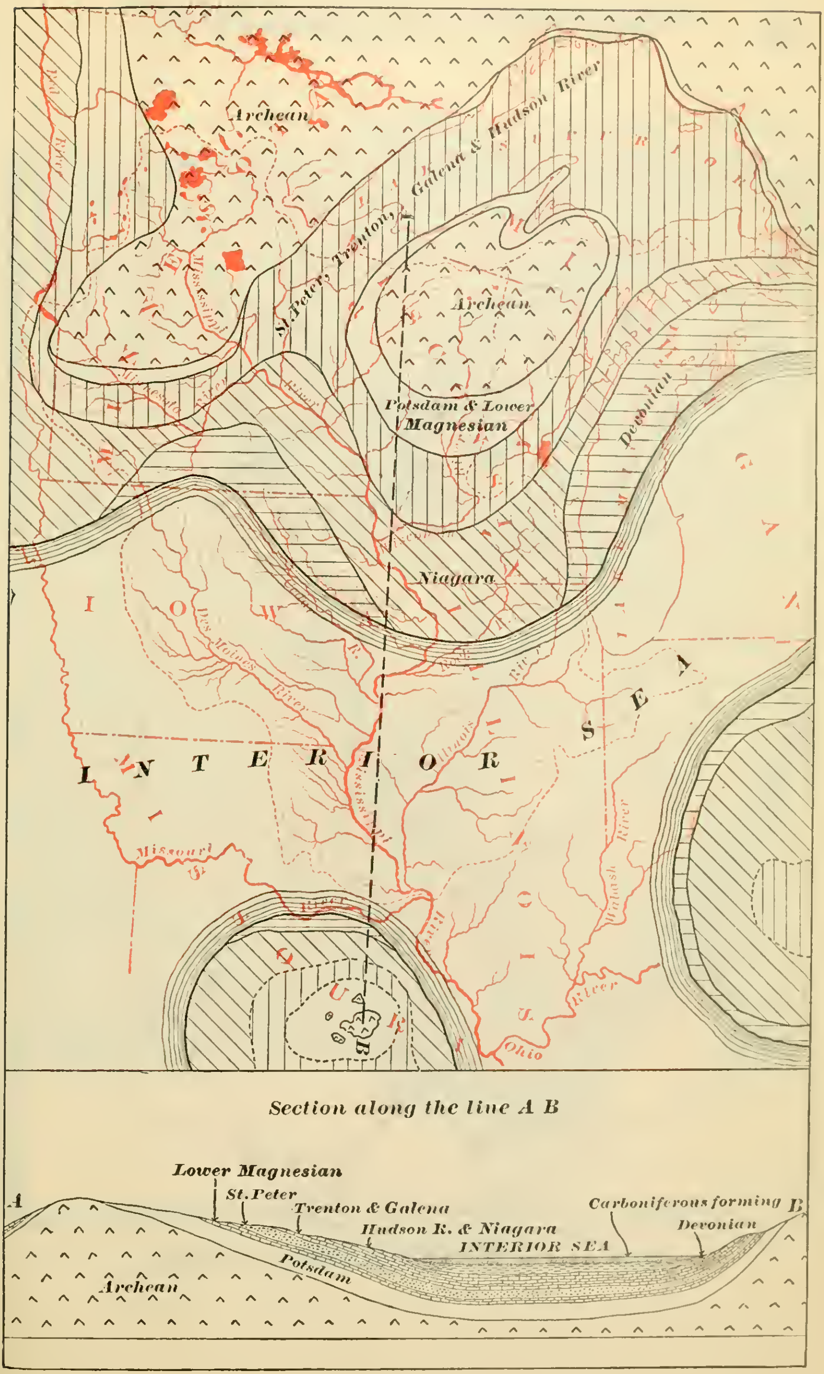
Map No. 4.



Niagara Period.

Niagara Deposits forming in Interior Sea.

MAP No. 5.

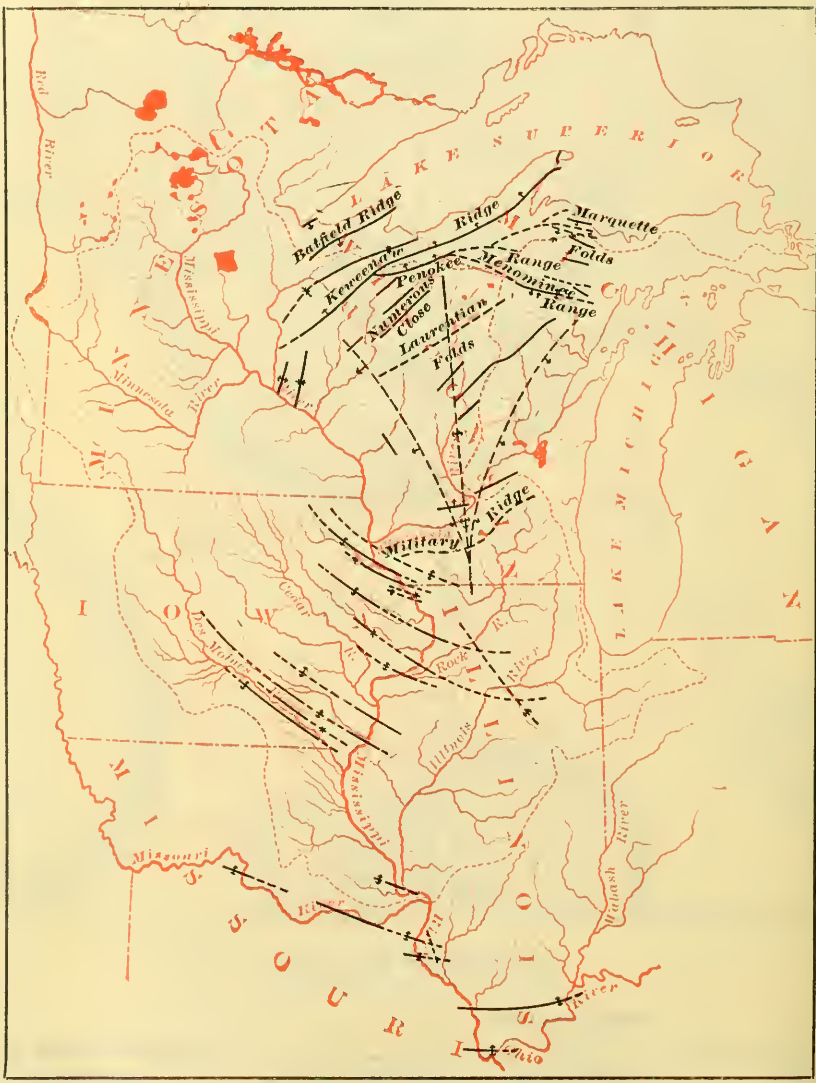


CARBONIFEROUS PERIOD.

Carboniferous Deposits forming in the Shallow Interior Sea.

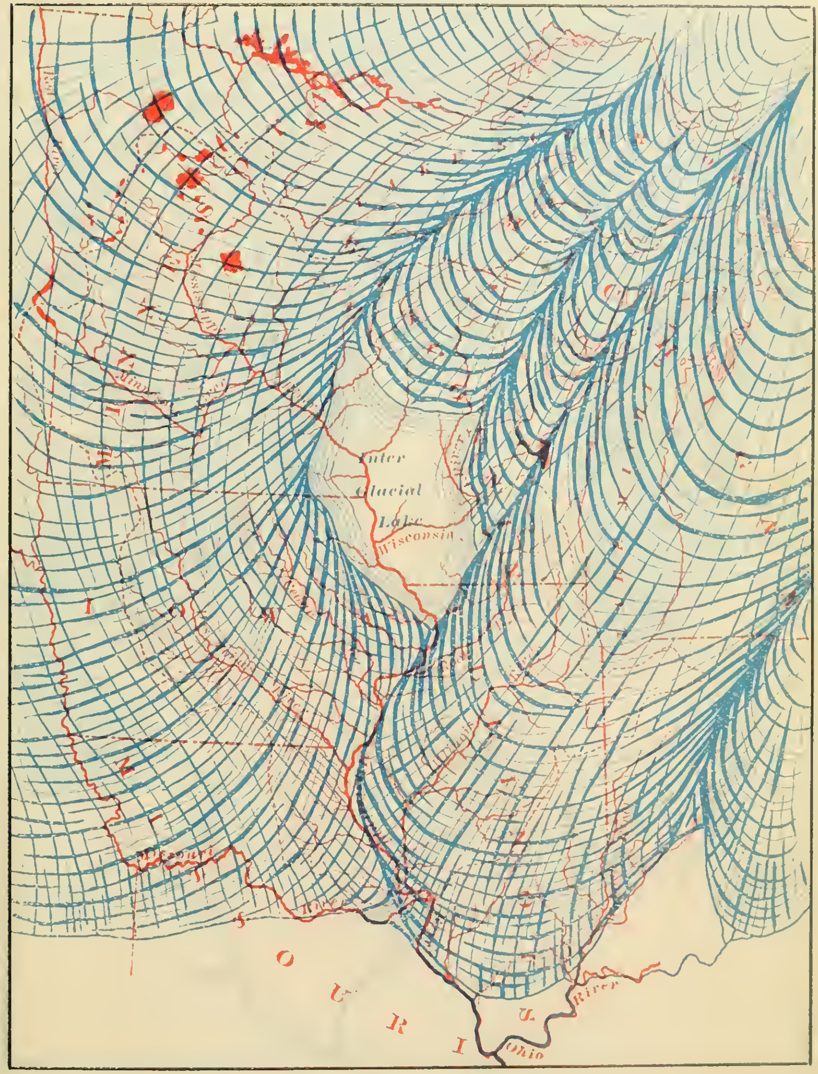
For Map No. 6, see large inset.

MAP NO. 7.



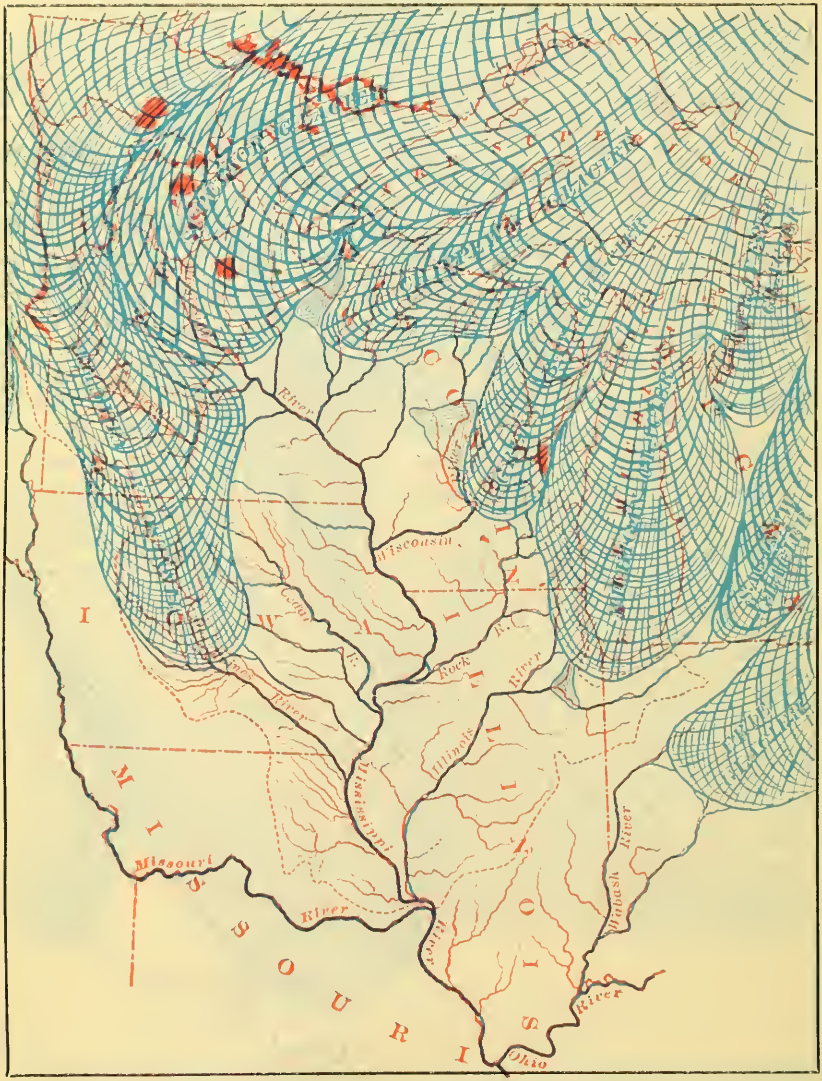
MAIN AXES OF DEFORMATION AND DIP OF STRATA.

Map No. 8.



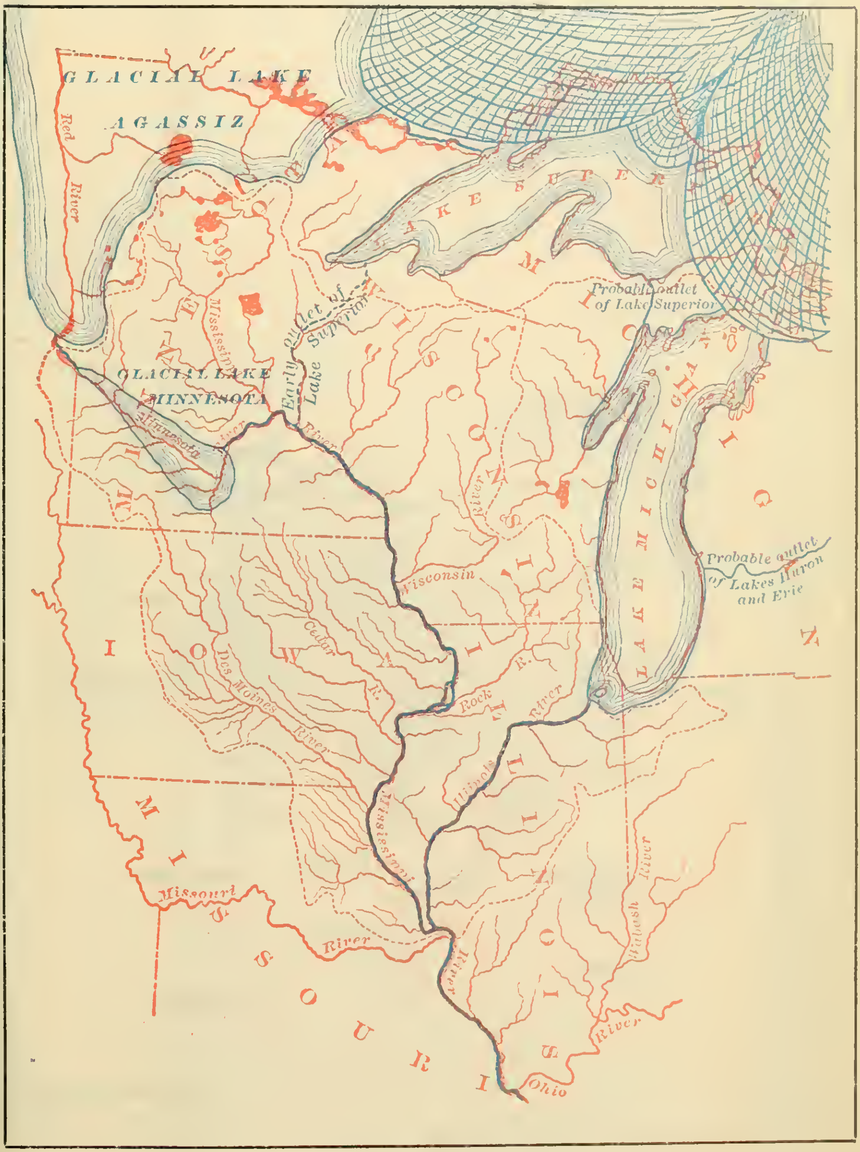
First Glacial Epoch.

Map No. 9.



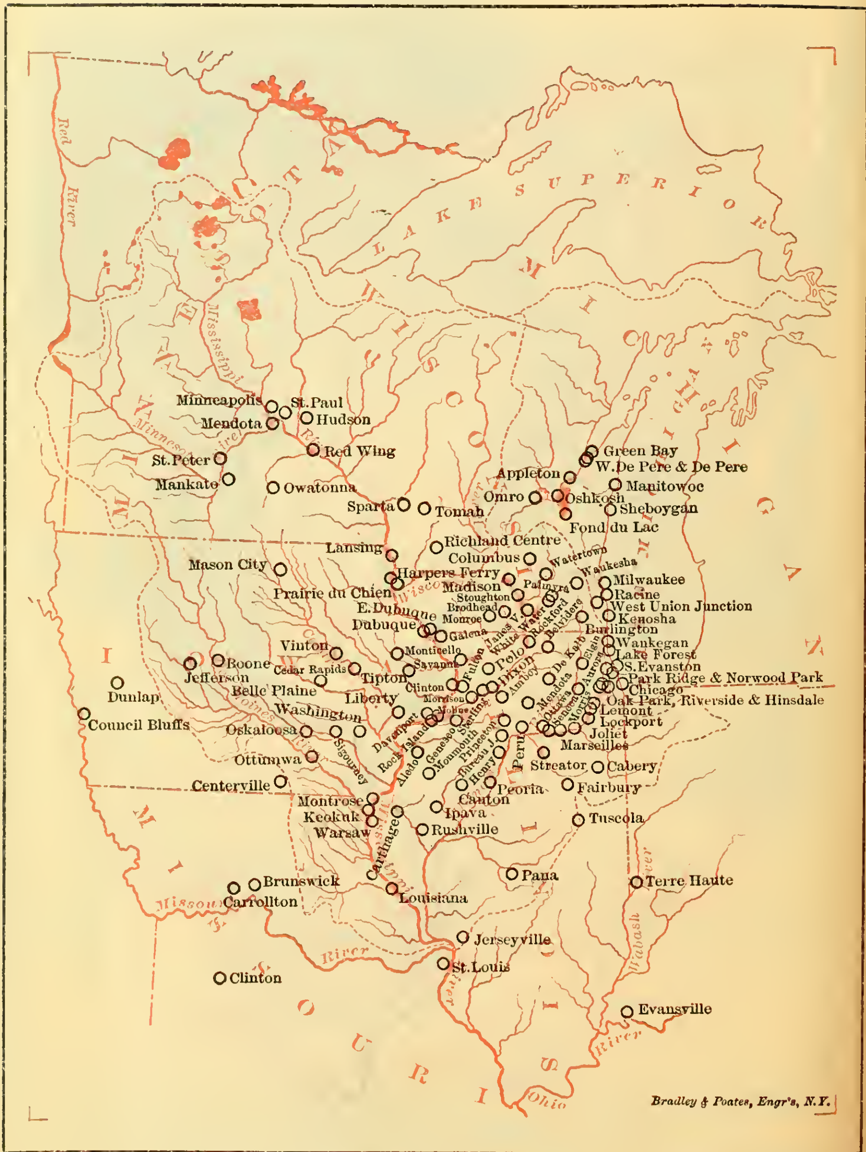
Second Glacial Epoch.

MAP No. 10.

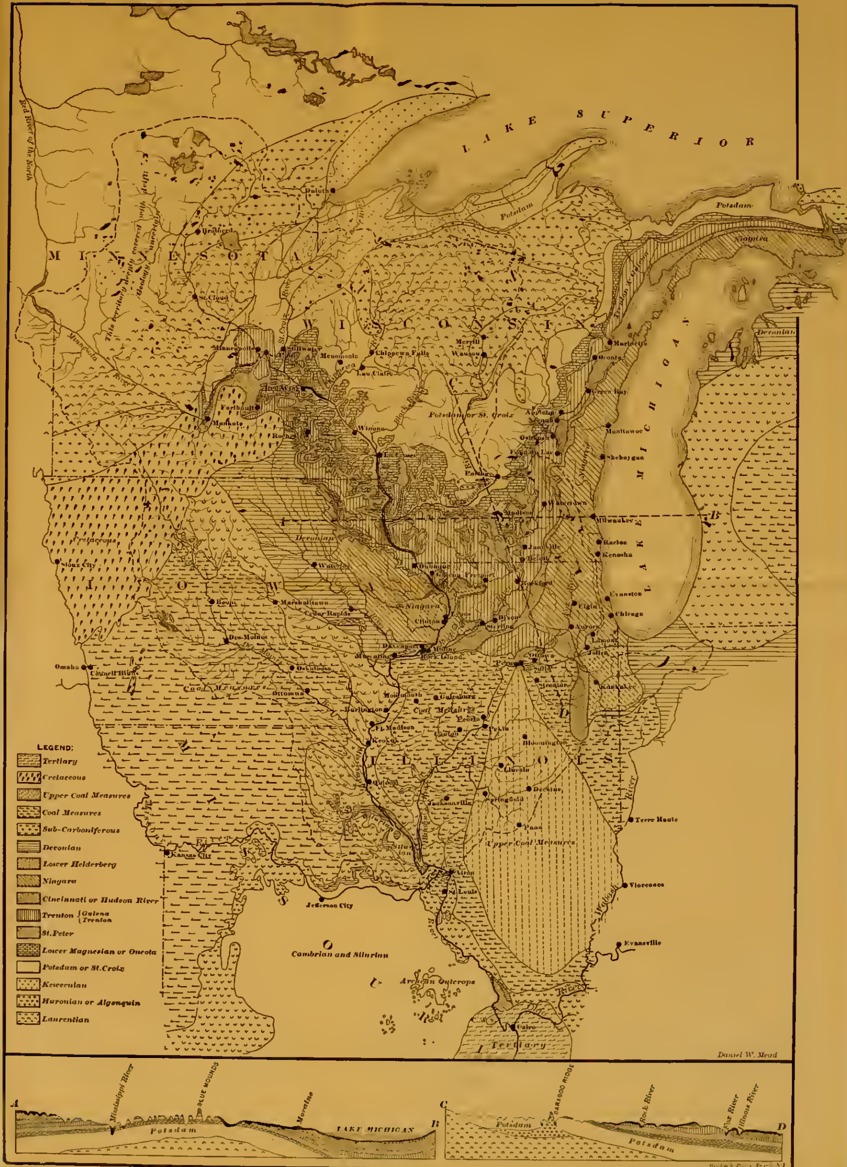


RECESSION OF THE GLACIERS.

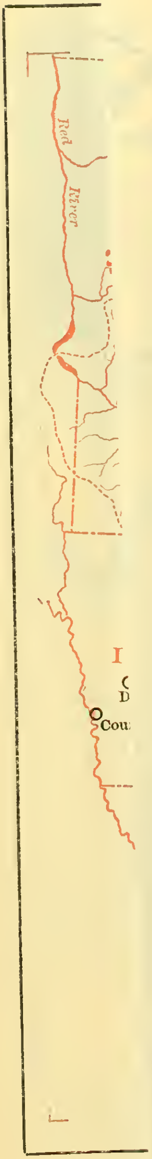
Map No. 11.



Artesian and Deep Wells.



APPROXIMATE GEOLOGICAL MAP OF THE UPPER MISSISSIPPI VALLEY, SHOWING INDURATED FORMATION.


Red
River

THE CONTRIBUTION BOX.

Members of the associated societies, and other persons, are invited to send to the Secretary, for this department of the JOURNAL, such matters of general interest as may come to their notice.

Cost of Earthwork.—A Correction.

The Collector finds himself under the disagreeable necessity of apologizing for having overlooked a vagary of the printer's devil, which resulted in a glaring and ridiculous blunder in presenting, in the May JOURNAL, the figures for cost of earthwork taken from Mr. Corthell's note-book.

The number of carloads hauled is correctly given as 32,141, although there was, of course, no necessity for adding a decimal point and two ciphers; and the total cost, $17,803.59, is also correctly given; but from these it follows that the cost per carload and per cubic yard are $0.5538 and $0.1107 (say 55 and 11 cents) respectively, and not one-tenth of those figures, as wrongly printed.

Pound Rates Again.

Within a year or two the Post Office Department has been more or less rigidly enforcing its rule to the effect that "a paper distributed among the members of a society, association, or club, upon payment of regular dues, and with no independent, distinct and sufficient charge for said paper, must be deemed as circulated at nominal rates or for free circulation, and treated as third-class matter." By this rule such publications as the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, issued for the sole purpose of disseminating useful information at cost and without profit, were compelled to pay one cent for each two ounces, while papers issued for profit and rejoicing in a good fat list of subscribers paying otherwise than as members of an association, were mailed in bulk at one cent per pound, which is really *less* than one-eighth of the former rate, for each copy of a third-class publication must be separately stamped according to its own individual weight, and if this contains an odd fraction of two ounces, in excess of a whole number of such units, such excess must pay its cent.

Upon the removal of the publication office of our JOURNAL from Chicago to Philadelphia, the pound-rate privilege was revoked. The January and February issues were mailed at pound rates under a temporary permit pending an examination of our application at Washington, but this temporary permit was in turn revoked, and the March, April and May numbers were mailed at the higher rate.

Thanks, however, to the good offices of Senator Charles F. Manderson, and of Representatives E. J. Hainer, Wm. M. Springer, David D. Aitken, J. G. Cannon, L. E. Quigg, A. J. Cummings and A. G. Caruth, and thanks, too, to vigorous letter-writing on the part of our Chairman, Prof. Johnson, and of the officers of other societies, the Post Office Appropriation Bill, containing an amendment extending second-class privileges (or the pound rate) to "all publications of strictly professional, literary, historical, or scientific societies," passed both houses

of Congress. The bill received the President's signature on July 16th, and the Association is thus again enabled to mail its JOURNAL at the same rates as are accorded to the *Police Gazette*.

Mr. Bernard R. Green, member of the American Society of Civil Engineers and a resident of Washington, who has been looking after the bill in the interests of his society, has kindly kept us advised of the progress made, and has greatly aided in enabling us to take early advantage of the passage of the bill. As we go to press, the June number of the *Transactions of the American Society* comes to hand, and without postage stamps, indicating that the Society also has availed itself of the provision of the new law.

Electric Lighting at Union, Mo.

The electric lights in the town of Union, Mo., were successfully started on the evening of June 6th, the event being made the occasion of a great celebration. This plant, which was designed by Mr. William H. Bryan, Consulting Engineer, of St. Louis, presents some novel features. The lights are operated from Mr. A. A. Tibbe's Westinghouse station at Washington, Mo., ten miles distant. The current used on the primaries in Washington and Union is 1,000 volts, alternating. At Washington a step-up transformer is used. This raises the voltage to 4,000, and the current is then transmitted over a pair of No. 8 wires, a step-down transformer being located at the entrance to the town of Union. The service in Union consists at present of 250 16-c. p. commercial lights, five 50 and sixteen 32-c. p. street lamps. Although Union is a town of less than 1,000 inhabitants and the consumption of light there is necessarily limited, the recent advancements in transformer construction and the low cost of copper have made it possible to handle this service profitably from the Washington plant. It is estimated that with the average load, the losses due to transformation and transmission will not exceed 5 per cent.

Improvements at the Massachusetts Institute of Technology.

During the past year the hydraulic laboratory of the Massachusetts Institute of Technology has been added to by the purchase of several pieces of apparatus of considerable size. Among these may be mentioned a Pelton wheel, a large steam pump, a new Pitot tube, a Ritchie-Haskell meter and a weir tank with adjustable sides.

The Pelton wheel is a 48-inch 30-horse-power wheel, and is set up in the laboratory in such a way as to be available for experimental purposes. The housing is arranged with glass windows so that the motion of the wheel can be seen.

The steam pump is a duplex Blake pump capable of pumping 2,000 gallons per minute.

The Pitot tube is a French adaptation of the well-known instrument, and is used for measuring the velocity of jets or currents of water under various conditions.

The Ritchie-Haskell meter is the well-known instrument largely used by the Geological Survey.

The weir tank is a large iron tank with a weir at one end, over which the

water flows into troughs which conduct it into measuring tanks. The essential feature of the apparatus is that the sides of the weir are arranged in such a way as to be adjustable, so that weirs of different lengths can be experimented upon. The laboratory is now equipped with a very complete set of apparatus for experimenting on weirs.

The laboratory has also been equipped with a very complete system of apparatus for experimenting on hose nozzles.

During the past three years experiments have been made on riveted joints in bending, such as the splice of a plate girder web exposed to bending.

A series of experiments carried on during the past year or two relates to the shearing strength of timber along the grain, when the shearing force is oblique to the plane of failure. This has its application in Howe truss blocks and in various timber structures, and the results will be of considerable interest.

A National Public Works Convention.

The proposed National Convention of members of Boards of Public Works, suggested by Mr. M. J. Murphy, Street Commissioner of St. Louis, and mentioned in the Contribution Box for March, has been called to meet in Buffalo, N. Y., in September next.

Preservation of Railroad Ties.

Some of our American railroads are beginning to avail of the economy of preserving ties against decay by chemical treatment, and the results are beginning to tell, particularly with Burnettizing, which is the favorite process, and all but universally employed in Germany.

From data furnished recently by Mr. Chanute to *Engineering News* (issue of June 28, 1894), we note that from 1885–6 to the close of 1893, some 1,298,884 ties, treated by the zinc-tannin process of Burnettizing, have been laid on the Atchison, Topeka and Santa Fe Railroad, and 2,148,502 on the Chicago, Rock Island and Pacific Railroad. Of the latter only 16,601 had been renewed to the close of 1893. These were of hemlock and tamarack timber, and it was estimated that 1.6 per cent. had come from the ties laid in 1887 after six years' exposure, and 8.6 per cent. from the ties laid in 1886 after seven years' service, thus leaving 91.4 per cent. of the latter still in the track.

This, together with an experiment on the Atchison, Topeka and Santa Fe Railroad, dating back to 1881, which shows that 40 per cent. of fifty Colorado pine ties were yet in the track after 11.83 years exposure, indicates that the average life of ties treated by the zinc-tannin process will not be less than 12 years.

Unprepared oak ties cost about 53 cents each, and some 25 cents more for hauling, distributing and laying, making a total of 78 cents each. Hence, as they last 8 years, their average annual cost is 9.66 cents. The Burnettized ties are said to cost 72 cents each under the like conditions, and, as they last 12 years, the average annual charge is 6 cents, thus indicating an economy of 3.66 cents per year per tie, or, when 2,640 are laid per mile, of $96 per year per mile of track.

THE LIBRARY.

It is proposed to notice briefly in this department of the JOURNAL such engineering publications as may find their way to our shelves.

Publishers are requested, in sending works for review, to state the prices of same.

Flying Machines, PROGRESS IN —. By O. Chanute, C. E. New York: The American Engineer and Railroad Journal, 1894. 290 pages; $5\frac{1}{2}$ x $8\frac{1}{2}$. Index, 18 pages.

That the study of aërial navigation has now become something more than a mere diversion, is evidenced by the profound attention and the great labor bestowed upon it by serious, practical engineers like Maxim, Wellington and the present author. The book before us, although not a large one externally, is closely printed, and it embodies the results of an immense amount of painstaking research.

In his Preface the author states that his object in preparing the work was threefold: first, to satisfy himself whether we may now reasonably hope eventually to fly through the air, a question which he believes may be answered in the affirmative; second, by recording the innumerable failures which have occurred, to warn other experimenters from similar attempts; and, third, to render an account of recent progress in the direction of aviation and to state the principles of that art.

The book, as indicated in its title, ignores the gas balloon and confines itself solely to devices for mechanical flight.

In treating of the principles involved, the author points out that the normal pressure of the air against a surface inclined to the direction of the wind is considerably greater than what it would be under the ordinary assumption that it varies with the sine of the angle of inclination, and gives a table of results obtained by Prof. Langley, which indicate that the formula attributed indirectly to Bossut and to Duchemin is approximately correct. This formula is:

$$P = P' \frac{2 \sin a}{1 + \sin^2 a}$$

in which a = the angle of inclination, P the pressure normal to the inclined surface, and P' the pressure upon a normal surface of the same area.

Devices for mechanical flight are divided by the author into three grand classes: wings and parachutes, screws to lift and propel, and aëroplanes, the latter being "thin fixed surfaces slightly inclined to the line of motion, and deriving their support from the upward reaction of the air-pressure due to their speed, the latter being obtained by some separate propelling device."

The first authenticated case mentioned by the author under the first-named class is that of Leonardo da Vinci, painter, sculptor, architect and engineer, and dating from about 1500. This and a number of other devices for employing the muscular power of man for the manipulation of wings, are described and illustrated, and our author then proceeds to the consideration of similar devices worked by various other motive powers, such as those of twisted strings, etc. Among these is the remarkable device of Trouvé, in which a Bourdon tube, similar to that of an aneroid barometer, is made by successive explosions of cartridges to contract and expand spasmodically, thus giving motion to a pair of wings.

Both Leonardo da Vinci and Trouvé experimented also with machines of the second class, or screws for lifting and propelling, and our own Edison, at the instance of Mr. James Gordon Bennett, in 1880 made some experiments with a view to ascertaining what power could be exerted by such apparatus. The motor exhibited by Trouvé in 1887 at the Scientific Congress at Toulouse, and in 1888 before the French Société de Physique, said to be the lightest ever built, weighing but 3.7 ounces, and developing 868 foot-pounds per minute, is illustrated and described.

Much the larger portion of the book is devoted to the third class of flying machines, or aëroplanes, which appear to have been among the first devices employed for aërial navigation, and to have engrossed the attention of the latest experimenters. Even as early as the first century, A. D., it is said that Simon, the Magician, undertook to fly by means of an aëroplane, but was brought down by a well-directed prayer from St. Peter, who seems to have been conveniently upon the spot.

A very interesting sketch is given illustrating the flight of a sparrow-hawk from its hole in the side of a tall aqueduct, near its top, and its return to the same place, with no further effort than the utterly inappreciable exertion of opening and folding up its wings twice.

A very curious phenomenon discussed under the head of aëroplanes, and one which appears to be allied to that where a ball remains suspended in a jet of air inclined upward at an angle of about 45°, is that of aspiration, by which a body, such as that of a bird, instead of being driven before the wind, is, to a certain extent, drawn toward or against it; and a very pathetic account is given of the struggles of one Capt. Le Bris, a French mariner, who found that the wing of an albatros, when held exposed to the wind, drew him forward into the wind. He constructed various machines, with some of which he had very fair and encouraging success, but enough of failure to call down upon him the ridicule of the spectators, and to bring about the enforced abandonment of his experiments. And yet the same principle is said to have been employed in the kites designed by Mr. C. E. Myers for services in the recent rain-making experiments.

A number of forms of Chinese kites are illustrated. These, as is well known, fly without tails, their flexible bodies enabling them to adjust themselves as need be to the wind. The chapter on aëroplanes concludes with accounts of the modern experiments of Phillips, of Hargrave, with his cellular kites, of Maxim, with his investigations of the supporting power of aëroplanes, of Trouvé, who, in 1891, deposited with the French Academy of Sciences a sealed letter containing descriptions and drawings of an aëroplane, which he believes is destined to solve successfully the problem of aërial navigation, and of Lilienthal, whose remarkable flying experiments in the neighborhood of Berlin are illustrated and described at length in an appendix entitled, "The Flying Man." At the close of this chapter the author states the conclusions to which his investigations have led him, in which he is far from abandoning hope of a successful issue of the labors which are now being performed, and expresses the hope "that the advent of a successful flying machine, now only dimly foreseen and nevertheless thought to be possible, will bring nothing but good into the world; that it shall abridge distance, make all parts of the globe accessible, bring men into closer relations with each other, advance civilization and hasten the promised era in which there shall be nothing but peace and good-will among men."

The book is furnished with a very thorough-going and comprehensive index of 18 pages, and it is a pity that the typography was not made such as to do justice to the enthusiasm and labor expended in the preparation of the material.

Frontinus and His II Books on the Water Supply of the City of Rome, A.D. 97. A lecture delivered before the engineering students of Cornell University, February 2, 1894, by Clemens Herschel, Hydraulic Engineer.

The orthodox historian has made history to consist so largely of the accounts of battles, that most of us probably find it difficult to outgrow our schoolboy impressions of Rome and the Romans as constituting practically little more than an armed camp, and it is truly refreshing to find in this pamphlet one of the engineering features of Roman life treated in such a way as to force us to realize that the ancients had other interests than those of mere fighting. Our author makes us feel almost personally acquainted with "this conscientious, honest old Roman Water Commissioner," whose character and whose works he handles with a loving interest. If more of history were written in this way it would prove a less formidable study.

Sextus Julius Frontinus is supposed to have been born about the year 40 and to have died in 103 A.D. He was a public officer during the reigns of Vespasian, Titus, Domitian, Nerva and Trajan. Under Vespasian, in 69 to 79, he is believed to have undertaken an important surveying operation, after which he wrote a treatise upon surveying. From 75 to 78 he was governor of Britain, and distinguished himself not only as a road builder but as a military commander. About 96, or when 56 years of age, he was made Curator Aquarum, or sole imperial Water Commissioner of the Water Works of Rome, and he almost immediately began compiling the treatise which forms the subject of Mr. Herschel's lecture.

This was practically his engineer's note-book. He went carefully over each of the aqueducts, noting its several features, and afterwards had plans of them made. These aqueducts are minutely described in his work. That he took an honest pride in the works under his charge, is evident from his remark, "Can anybody compare these wonderful works, serving so many needs of man, with the idle pyramids, or with those other useless, though much-renowned, works of the Greeks."

Mr. Herschel ridicules the idea that the ancient Romans were unacquainted with the principle of the inverted siphon, and points to their very extensive use of lead pipe to show that they must have been well acquainted with this principle. The well-known fact that their aqueducts were masonry structures built with a nearly uniform slope and crossing the valleys in elevated straight lines, is, he says, easily accounted for by the very simple fact that the ancients, while not unacquainted with the inverted siphon, were devoid of the means of applying it upon a large scale. Mr. Herschel tells us that Vitruvius, speaking of inverted siphons, states what the Greeks called them, and that remains of Greek pipe siphon aqueducts have been found in Asia Minor, and are shown in modern books of travel.

As far as possible, the Romans avoided the taking of river water, and sought far and wide for underground springs. When a river was taken, it was first passed through artificial lakes, which served as settling reservoirs.

Mr. Herschel accounts for the frequent bends in the aqueducts by the simple hypothesis that they were employed in order to join two lines which otherwise failed to meet.

Frontinus appears to have done much to reduce the slopes of the aqueducts. Vitruvius, one hundred years before him, had advised slopes of one in two hundred, while some of the later aqueducts were as flat as one in six hundred, or even flatter.

All of the waters furnished by the several aqueducts were very hard, ranging from 18 to 27 degrees of hardness. One of the aqueducts, Alsietina, furnished so bad a water that it was used only for irrigation and such purposes. The aqueducts ended generally in a large cistern, and from these the distribution was effected by means of lead pipe, made by bending leaden plates, of the proper width and some ten feet in length, into a pear-shaped cross-section, and soldering the joint with pure lead.

It seems difficult for us now to conceive of engineers having the ability to construct such works as the Roman aqueducts and yet unable to realize the effect of the velocity upon the discharge of a stream of given cross-section, and yet such must have been Frontinus' case, for, according to Mr. Herschel, Frontinus "compares streams of water merely by the areas of their cross-sections." He was, however, acquainted with the fact that the adjutage delivers different quantities from a given stream according as it is inserted with or against or at right angles to the current. He seems also to have been made acquainted, perhaps by direct contact with fraudulent practice, with the principle of the Venturi meter, which Mr. Herschel has done so much to bring to the attention of the public.

Mr. Herschel dissents entirely from the estimates of Rondelet and others of the quantities discharged by the Roman aqueducts. Rondelet puts this at 395,000,000 gallons per day, whereas Mr. Herschel believes it to have been not greater than about 136,000,000 gallons when all the aqueducts were running at their full capacity; and 50,000,000 gallons one day with another, is, he believes, a fair estimate of the water supply within the walls of ancient Rome in A.D. 97. Even this would give fifty gallons per day per inhabitant.

The author finds that the Roman aqueducts, so far from meriting unalloyed admiration as models of engineering excellence, may well be subjected to criticism both as to their construction and as to their operation, the records showing that they were constantly in need of repairs, as indeed must almost inevitably have been the case with these long masonry conduits, exposed as they were to violent changes of temperature.

Mr. Herschel is entitled to our thanks for this little work, in which he has shown not only how greatly we have advanced in scientific knowledge since the days of Frontinus, but also in how many and in how vital respects we still resemble the men of those days.

Society Proceedings.

American Society of Civil Engineers. Transactions of the ——. Vol. XXXI, No. 5, May, 1894.

In this number Mr. Robert Moore, of the Engineers' Club of St. Louis, presents an illustrated account of the construction of the elevated railway forming the terminal to the Merchants' Bridge in that city. Mr. Archibald A. Schenk discusses the Relation of Wheels to Frog Points and to Guard Rails; and Mr. M. Meigs describes the Use of Canvas in Watertight Bulkheads, as illustrated in the United States Mississippi River Canal, at Keokuk, Iowa, and as applicable in other cases. A short paper by Mr. Addison M. Scott describing the movable dams on the Ohio River, is illustrated with views of the Pasqueau heurter, to which the application of the Chanoine wicket to our large American streams may be said to owe its feasibility, and is discussed by Col. Wm. P. Craighill, the officer in charge of the work and President of the Society, and by Mr. J. P. Frizell, whose

discussion embodies a brief review of the operations of movable dams in general. The number contains also discussions on Dredging Operations and on the Storage and Pondage of Water.

Vol. XXXI, No. 6, June, 1894.

This number, which comes to hand as we go to press, opens with Col. Wm. P. Craighill's presidential address delivered at the recent annual convention, held at Niagara Falls. The burden of the address is the condition of our sea-coast defenses. Mr. Eugene Lentilhon describes the building of a concrete sewer on piles by the Dock Department of New York City. His paper is illustrated by two plates. Mr. Wm. Barclay Parsons, in a very brief paper, illustrated by two photographic views, relates the failure of a foundation on shale under the tall piers of the viaduct at Hornellsville, N. Y.; and Mr. Walter H. Gahagan describes and illustrates the reconstruction of a portion of the sub-structure of the bridge by which the Nashville, Chattanooga and St. Louis Railway crosses the Tennessee River at Johnsonville, Tenn.

Engineers' Club of Philadelphia. Proceedings of the ——. Vol. XI, No. 3, quarterly, April–June, 1894.

This number opens with a description, by Mr. Emile Geyelin, of the turbines installed by Messrs. R. D. Wood & Co., of Philadelphia, at the works of the Niagara Falls Paper Company. These were the first wheels to draw water from the new plant of the Cataract Construction Company, and the paper is therefore properly entitled The Baptism of the Great Niagara Tunnel. Mr. E. M. Cook discusses Methods and Apparatus for Drying with Heated Air, and Mr. A. Falkenau describes at length and illustrates the pneumatic postal system recently installed between the main Post Office in Philadelphia and one of its branch offices. This is the first pneumatic system installed in the United States, and its tubes, 6½ inches in diameter, are much larger than any others used for this purpose. Their preparation involved some very exceptional work, which was undertaken and performed by Mr. Falkenau. The paper was discussed by Postmaster Carr, by his predecessor, Mr. John Field, who was very largely instrumental in securing the installation, and by the President and Engineer of the Construction Company, all of whom were present by invitation. Mr. L. Y. Schermerhorn, formerly Principal Assistant to the U. S. Engineer stationed in Philadelphia, and now President of the American Dredging Co., discusses the Improvement of Philadelphia Harbor. The reading of his paper led to a lively discussion, in which a prominent part was taken by Prof. L. M. Haupt, who took exception to some of the views expressed and the methods adopted. Mr. Joseph T. Richards, Engineer of Maintenance of Way of the Pennsylvania Railroad, gives a chatty account of the rebuilding of that road after the great floods of 1889, and Mr. W. Copeland Furber describes the erection of two large new office buildings in Philadelphia.

Engineers' Society of Western Pennsylvania. Proceedings of the ——. Vol. X, No. 6, June, 1894.

This number contains merely the minutes of the meeting of June 21st, five pages, one page of announcements and five pages of advertisements, exclusive of the cover. If the members of our societies would bring our advertising space into something like similar ratio to our reading matter, they would render possible a material reduction of the assessments.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XIII. AUGUST, 1894. No. 8.

THE WEST GALLATIN IRRIGATION CANAL, MONTANA.

BY A. E. CUMMING, MEMBER OF THE MONTANA SOCIETY OF CIVIL ENGINEERS.

[Read April 8, 1893.*]

THE idea of constructing a canal to convey water from the West Gallatin River for the purpose of irrigating the high bench lands lying west of that river and between it and Madison River, in Gallatin County, Montana, was first conceived by Mr. Charles A. Gregory, of Chicago, in the summer of 1889. A reconnoissance and an estimate of the cost of the proposed works was made by an engineer who had previously acquired fame by his connection with the Florence canal and other enterprises, to which, by the way, he usually applied the term "scheme," a fitting one for many of them.

All I care to say of his estimate of the cost of this enterprise is, that it was less than $100,000, and contemplated building a canal 30 miles long, 6 miles of which were to be 25 feet wide on the bottom, and to carry 5 feet of water along a steep side-hill with an average slope of about 3 to 1.

With this estimate as a basis of calculation, a company composed of New York and Boston capitalists was formed to construct the canal. A contract was entered into between Charles A. Gregory and the Northern Pacific Railroad Company for the purchase of 28,000 acres of land, and an agreement was made to construct the canal with the following dimensions:

* Manuscript received July 10, 1894.—*Secretary.*

The first ten miles were to be 25 feet wide at bottom; the next ten miles 20 feet, and the last ten miles 14 feet. The depths were to be 5, 4 and 3½ feet respectively. It was estimated that these thirty miles of canal would suffice to water the entire bench land.

In the spring of 1890, I was employed to make the preliminary surveys, and our worthy president was commissioned consulting engineer. I ran sixty miles of careful preliminary line, and the cost was estimated by the consulting engineer to exceed $250,000. The report completely paralyzed the financial managers of the company, and they advised the immediate abandonment of the project.

Mr. Gregory went East to rally the panic-stricken financiers, but, after several weeks of hard work, he gave this up as a lost cause and turned his attention to reorganization in a different form, coming to Helena to consult with his engineers as to the probable cost of a smaller canal. Our consulting engineer was then engaged in other works and could not spare the time necessary for making the estimates needed, and that duty fell to the writer.

Considering that very little water would be used on any land then under cultivation, and that for some years only those who bought land of the company would want water, and recognizing the fact that such lands as these are usually settled very slowly, it was decided to materially reduce the size of the proposed canal for the present, leaving it to be enlarged as the needs of the company demanded. I was, therefore, instructed to make an estimate for the first twenty miles of a ditch, or canal, as it was called, 12 feet wide on the bottom, to carry 3 feet of water.

This was estimated to cost $62,000, and a company was formed and money subscribed for the work. The contract with the Northern Pacific Railroad Company was revised so as to conform to these new conditions as to size and length, and work was begun on November 1, 1890, when ground was broken on a contract let for the first one and a half miles.

In making a survey for an irrigation canal system, a reconnoissance should first be made, the head-works approximately located and a grade contour run to determine the approximate location of the entire main canal. After this the definite location of the head-works may be made either higher or lower than was at first contemplated, in order to suit existing conditions as determined by the grade contour. As the head of the canal must be raised if it is found desirable to reach points higher than the grade contour, great care should be exercised, before construction work is begun, in definitely locating the head-works of a canal system.

The preliminary line run for the larger canal, originally proposed, was used as a basis on which to locate the head-works of the smaller

one. The soil of the country through which the canal would pass was clay loam of a depth varying from 2 to 6 feet and underlain by either gravel or alkaline rock. After examining the effects of grades on other ditches in the valley, it was decided to adopt a grade of .06 feet per 100 feet, or 38 inches per mile, and the thirty miles of the canal was constructed on this grade, except that the first quarter mile from the head-gate has a fall of 2 feet.

The head-gate, Figs. 2, is of wood. 8 inch x 12 inch timbers were used for posts and sills, and usually 6 inch x 8 inch for braces. The whole structure is well sway-braced with 3 x 12 inch plank, as shown. It has five independent gates, each 3 x 4 feet in the clear. Up-stream from the gate an 8 inch x 12 inch timber T is sunk in the bed of the stream one and a half feet below the bottom of the gate, and a two-inch plank apron A is spiked to this and to the sill of the head-gate, to prevent the water from washing out under the gate. At the south side of the gate (see Fig. 1) is a timber crib filled with stone and earth to prevent washing around the end. The north side is heavily riprapped.

In June, 1892, the water in the river rose to within one foot of the top of the gate. That it stood the pressure then is a very good test of its strength, and is sufficient security of its withstanding future demands, for at that time the water in the river was the highest ever known.

At the location of the head-gate the bottom land on the opposite bank of the river is from one to two miles wide, and extends for two miles above and for several miles below this point. This rendered it impossible to construct a weir across the river without running great risk of serious damage to valuable farms during the high-water season. The river, at this point, has a fall of over sixty feet to the mile, and, as the raising of the surface of the water in the river was of no advantage, the bottoms of the gates were placed three feet below low water mark, so that when the gates were closed there would be three feet of still water standing against them. The first quarter mile of canal is 24 feet wide at the bottom, and at its end is placed a waste-gate to turn back into the river, if desired, any water that may run in the canal.

At a low stage of the water, the bottom of the canal at this waste-gate is five feet below the surface of the river at the head-gate, and from this it is apparent that by closing the waste-gate a depth of five feet of water, if needed, can easily be attained in the canal below this point, provided, of course, there is sufficient water in the river to supply it. I will say in this connection that the river is over 100 feet wide, and 2½ feet deep; and, as I said before, has a fall of 60 feet per mile. This should remove any doubt as to the ability of the river to fill a canal 5 feet deep and 14 feet wide.

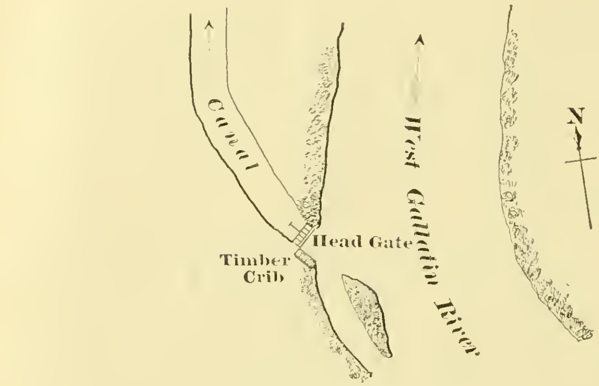
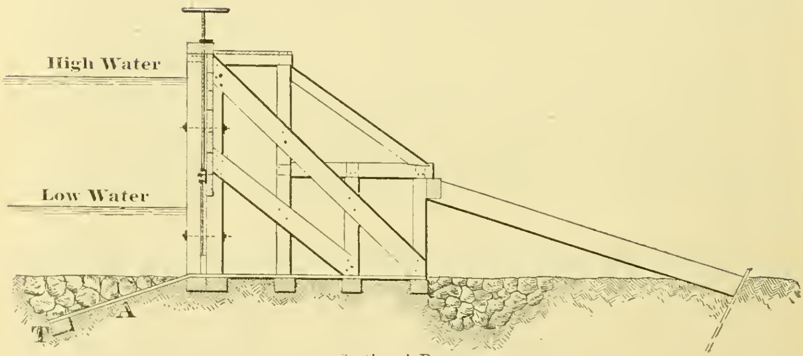
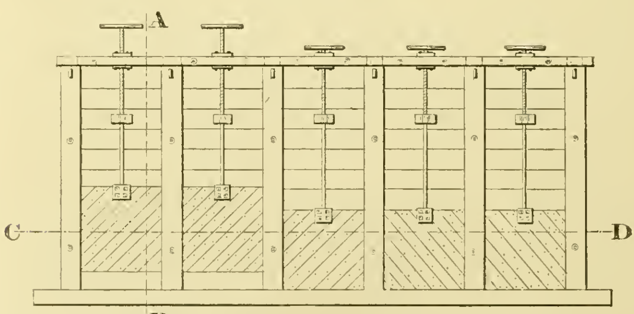


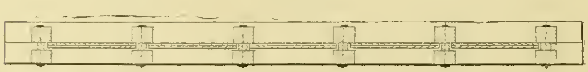
Fig. 1.—Scale 1 = 3000.



Section A B.



Elevation.



Section C D.

Figs. 2.—Head-Gate. Scale 1 = 115.

At the waste-gate the bottom width of the canal was reduced from 24 to 14 feet, and the depth of water to 4 feet, and these dimensions are carried through the remainder of the first twenty miles. The first half mile is built on a low bench along the bank of the river, but far enough away from the main channel to prevent any damage to it from high water in summer, or from ice in winter.

For two miles below this point the canal runs through cultivated fields and is dug full four feet deep, in order to prevent flooding of the fields when the canal is full of water, as well as to enable us, at the crossing of three smaller ditches now in operation, to carry them over the canal in flumes. At the end of three miles the canal reaches the foot of the high bluffs or table lands skirting the west bank of the river, and follows along the bluff, gradually approaching the top, until it reaches the tunnel at the end of the tenth mile. Most of the eleventh mile is located just along the top of the bluff, where there is a depth of from three or four inches to a foot of earth on top of a very hard granite ledge or bed-rock. Most of this mile was located by so placing the center line that the intersection of the bottom of the canal with the upper slope would be on the rock, a levee being built up on the lower side to hold the water. This obviated deep rock cutting.

Where side gulches, draining a considerable area, were crossed, the canal was carried over them in wooden flumes, Fig. 3, and waste-gates

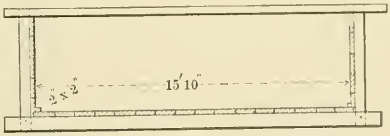


FIG. 3.—SECTION OF FLUME. SCALE 1 = 115.

were constructed in these flumes to relieve the flood in the canal when necessary. Such gates are especially necessary in this particular locality, where cloud-bursts, or very heavy showers, are of quite frequent occurrence during the month of June. During one of these storms 4 inches of water, by actual measurement, fell in fifteen minutes.

These flumes, 15 feet 10 inches wide in the clear, usually with the same fall as the canal, are built of 6 inch x 8 inch timbers, laid with their centers 3½ feet apart, for the sills; 4 inch x 6 inch timbers for the uprights, and 4 inch x 4 inch for top cross-pieces. The bottoms are of 2 inch, and the sides 1½ inch plank. The sides only are battened. The planks, of which the bottom and sides are constructed, were thoroughly seasoned, and were driven together as closely as possible. Usually, the center plank was placed in position and thoroughly spiked to the sills, and the next plank was driven up and held close to it by using levers and wedges between those planks that were merely placed in position,

and the one being spiked. In most cases, a very fair joint was thus made between the planks.

A longitudinal strip of 2 x 2 inch scantling was spiked along each inner and lower corner, as shown, in order to secure a good joint. When the flume was completed, its bottom was covered with loam or clay about one-fourth of an inch deep, and the flume was then ready to receive the water. About 450 feet of flume, of this style, was built on a trestle, the highest point of which was 50 feet above the ground. The trestles were built with 16 feet spans, and after the plans of ordinary railway trestles, with a factor of safety of four, and a person, driving alongside of these trestles eight or ten hours after the water was turned in, could detect no dripping.

The tenth mile of the canal was the most expensive of all, as it embraced about 2,000 feet of flume, 150 feet of which was on high trestles, and 243 feet of tunnel, while the balance was very heavy work along a steep side-hill composed of about equal quantities of earth, gravel, and rock. The larger part of the rock encountered in the work was an alkaline clay, very springy, but easily drilled. Two men, with churn-drill, could easily keep twenty muckers at work. Holes were put down, about one foot below the grade of the canal when possible. They were sprung with giant powder, and blasted with black powder. It was found that by using black powder for final blasting, very much better results were obtained than by using giant powder, and the cost was materially decreased. The cost of drilling and blasting averaged about 30 cents per cubic yard.

The tunnel was 243 feet long, 12 feet wide, and 6 feet high, with a grade of 1 foot per 100 feet for 200 feet, and the balance level. Only about 75 feet of this tunnel was timbered, the balance being in very hard granite. There was nothing of unusual interest connected with the construction of this tunnel, except that, for 25 feet, near the center, the top of the rock was identical with the top of the tunnel, and, when excavated, exposed the gravel subsoil.

The depth of the tunnel, below the surface at this point, was about 40 feet, and its greatest depth, below the surface, was 47 feet. By constructing this tunnel, 4,507 feet of line was saved. It cost about $2,000, but this is considerably less than the canal around would have cost, and the canal in the tunnel is very much easier to operate.

It will be noticed, that the estimate was made for a canal 12 feet wide at the bottom, to carry 3 feet of water, while it was built 14 feet wide to carry 4 feet of water. This very materially increased the amount of excavation from the fourth to the tenth mile, and, instead of costing $62,000, about 25 per cent. additional was required to complete the work.

In making approximate estimates of quantities, considerable annoyance was occasioned by the impossibility of obtaining tables of quanti-

ties suitable for the cross-sections obtained in ditch work, and, as the canal was in nearly all cases located on quite sloping ground, I found it necessary to deduce formulas from which tables could be easily prepared to meet each individual case. I had the preliminary line run with a uniform cut of two feet on lower slope, and had the slope of the ground at each station taken with an ordinary slope level or board, noting, at each station, the inclination of the ground for ten feet out. Two men can easily do this and keep up with the level party. The formulas are thus derived :

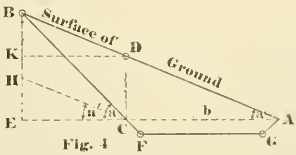


FIG. 4.

Referring to Fig. 4, let

$A =$ the area of the triangle, ABC, above the level cutting, $ACFG$.

$a =$ the angle, BCE.

$$\tan a = \frac{BE}{CE} = \text{slope, } BC\text{, in feet per foot.}$$

$a' =$ the angle, BAE.

$$\tan a' = \frac{BE}{AE} = \text{slope, } BA\text{, in feet per foot.}$$

$b =$ surface width, AC, of cutting.

$$\text{Then } A = \frac{b.\,BE}{2} = \frac{b.\tan a.\ CE}{2} = \frac{b.\tan a.\ CD}{2\,(\tan a - \tan a')}.^{*}$$

$$= \frac{b.\tan a.\,b.\tan a'}{2\,(\tan a - \tan a')} = \frac{b^2.\tan a.\tan a'}{2\,(\tan a - \tan a')}.$$

Where the slope is 1 to 1, $\tan a = 1$, and

$$A = \frac{b^2 \tan a'}{2\,(\tan a - \tan a')}. \qquad (1)$$

Where the slope is 1 1–2 to 1, $\tan a = \frac{1}{1\ 1\text{–}2} = \frac{2}{3}$, and

$$A = \frac{b^2.\ \frac{2}{3}\tan a'}{2\,(\tan a - \tan a')} = \frac{b^2 \tan a'}{3\,(\tan a - \tan a')}. \qquad (2)$$

The entire country through which this canal runs was filled with holes dug by badgers and squirrels, and we experienced a great deal of trouble in repairing the ravages caused by these animals, so that water could be safely run through the canal, except in very small quantities. At first only about two inches of water were allowed to flow in the new

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* $CD = BH = BE - HE = CE \tan a - CE \tan a' = CE\,(\tan a - \tan a')$.

$$\therefore CE = \frac{CD}{\tan a - \tan a'}.$$

or untempered canal, and that was very closely watched. When it was found to be escaping through a hole, the canal was emptied and the hole dug out to a depth of about four feet. If a badger's hole it was stopped with a sack filled with loam and clay, and then the earth was tamped very closely to the level of the grade of the canal. If a squirrel's hole, rock or gravel was driven into the hole, which was then filled up as before. The entrance to the hole outside of the canal, if it was freshly dug, was filled up. My experience with the animals taught me that if this entrance was not filled with rock or with some other hard material, the animals, if no one was in sight, would go into the hole and begin digging as soon as the water stopped running.

In Colorado, New Mexico, California, and all of the arid regions more southerly than this, and where the seasons are consequently longer and the crops more varied, a miner's inch of 17,000 gallons per twenty-four hours, may serve nearly two, and in some localities three, acres of land; but this holds only where the crops are so varied that when one crop is served with water, it may be turned on to another just ready to receive it, so that the water can be used for several months during the season. In Montana, the water must be used within about thirty days, unless the season is a very favorable one. Within fifteen days after any part of a crop is ready for water it must have had the water on it for the first time, or it will be burned and ruined. In warm weather, a crop will be damaged to the extent of 10 to 30 per cent., if the water is not applied within three days after the crop begins to show the need of it. Owing to the limited time during which water may be used to advantage, it becomes necessary to provide at least 1¼ inches per acre, and still more for areas less than 100 acres. Large areas of land to be irrigated from the same head-ditch or lateral may possibly be served with 1 inch per acre.

Another important factor in determining the sizes of canals is that embraced under seepage and evaporation. The first, of course, varies greatly, and scarcely any two localities will be even nearly alike in this respect, but the evaporation ought to be nearly constant for any locality, and for a given temperature. As these two cannot well be determined separately, any data determined for one locality or canal, will be somewhat unreliable for others.

During the middle of July, after water had been running in the West Gallatin Irrigation Company's canal, for thirty days, a depth of 8 inches of water at the waste-gate delivered at the end of twenty miles, a stream of water some 6 inches deep. I did not determine actual quantities in cubic feet or in miner's inches at either place. The decrease noted was undoubtedly far in excess of what it would have been with a full canal, when the wetted surface for seepage would have been relatively less.

MANITOU AND PIKE'S PEAK RAILWAY.

By Thomas F. Richardson, Member of the Boston Society of Civil Engineers.

[Read February 21, 1894.]

The Manitou and Pike's Peak Railway, as its name indicates, runs from near the town of Manitou, Colo., to the summit of Pike's Peak, a distance of 8.9 miles.

Manitou is a well-known summer and tourists' resort, famous for its great variety of mineral springs. These springs and the numerous points of scenic interest in the immediate vicinity, principal among which is Pike's Peak, make Manitou the famous resort which it is, the hotels and kindred industries constituting practically the only business in the town.

Pike's Peak is one of the highest mountains in the United States. Standing as it does on the edge of the great plains, the passenger coming from the East sees it from a distance of a hundred miles or more, and its situation makes it appear higher than it really is. It is also one of the best-known mountains in the country, the old saying of the "Eighteen Forty-niners," "Pike's Peak or bust," being familiar to all.

In 1806 Zebulon Pike, after whom the peak is named, saw it from one of its foothills, Cheyenne Mountain, and pronounced it inaccessible; but a rude trail to its summit was built in the early fifties, and since then several other trails have been built. The horseback trail leading from Manitou, close to the present railway line, was built in 1877, and until the railway was built, several thousand tourists reached the summit each year by means of this trail, each paying one dollar toll. In places, the grades on this trail were as steep as 35 per cent., and there were numerous sharp turns or switchbacks.

Tourists, however, always felt amply repaid for their laborious trip by the grand and beautiful scenery through which they passed and by the magnificent view from the summit.

In 1888 a carriage road, using a 10 per cent. grade, was opened, and over this a regular line of coaches was run from Cascade, a small town six miles above Manitou in Ute Pass. This line began doing a heavy business as soon as it was opened.

The people of Manitou now saw that they were likely to lose one of their chief attractions, and that something must be done. Accordingly, late in the fall of 1888, they raised a subscription in order to have a survey made for a railroad. This survey demonstrated that by

using 25 per cent. grades a comparatively cheap and direct railroad could be built.

In 1883 a survey for a narrow-gage railroad from Manitou to Pike's Peak was made, and about six miles of grading were done in the

Yard at Manitou, from Station 457. Sidings to Car Shed and Engine House.

following year. This railroad was to be twenty-eight miles long, with a 6 per cent. maximum grade, but in one or two places it was found necessary to use 7 per cent. The maximum curvature was 40 degrees. On

the first six miles the longest tangent was 300 feet, and the alinement averaged a 20-degree curve for the whole six miles.

This road would probably have been completed had it not been for an adverse report by an engineer sent out to report on the road by the capitalists who were expected to take the bonds. He reported that it would be impossible to maintain the railroad on the steep mountain slopes and that the road would be washed away.

The writer has been over the six miles of completed grade, and it is in as good condition as when the laborers left it, showing that even an engineer may sometimes err in his judgment.

Had this road been completed it could hardly have been operated profitably, for, owing to the sharp curvature and heavy grades which were to be worked by adhesion only, the cost of operation must have been great, and it is very questionable whether it could have been operated safely, for the rails are liable at times to become coated with ice or sleet.

In making the survey of 1888 it was borne in mind that the cost must be kept low if the investors were to get any returns on their investments, for the season during which the road can be operated lasts for only three and one-half summer months.

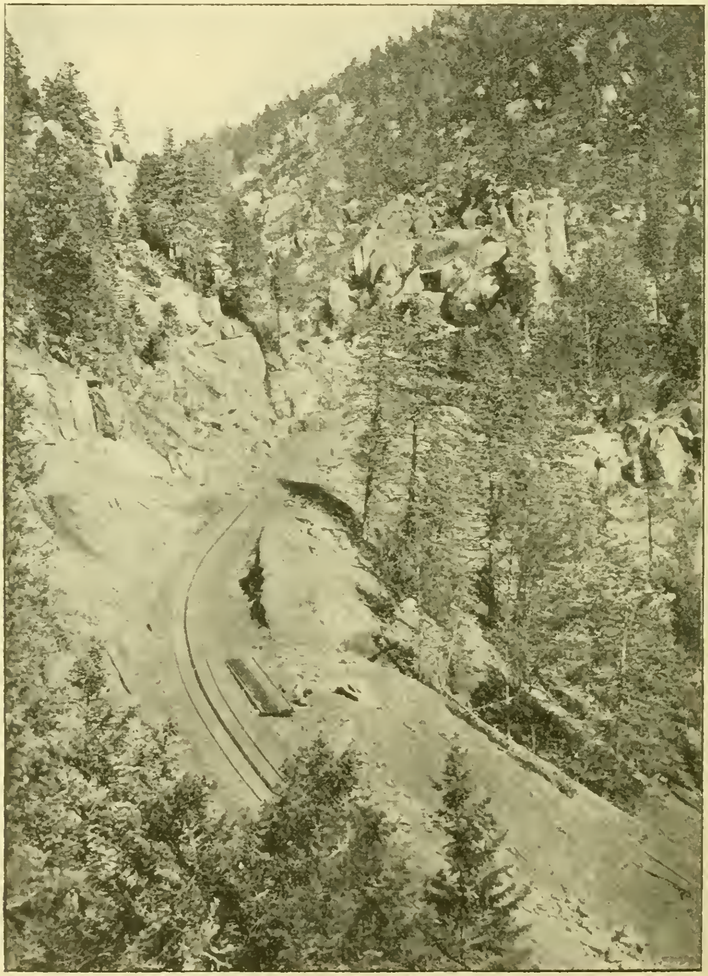
The success of the railroad up Mount Washington and of the two railroads up Mount Rigi in Switzerland had shown that it was possible to use 25 per cent. or even steeper grades if a rack rail was used, the maximum grade on Mount Washington being 37 per cent. for a short distance. The Abt rack was selected as embodying the best form, although up to this time it had never been used on as heavy a grade as 25 per cent. Twenty-five per cent. was decided on as maximum and 7 per cent. as minimum grade. The maximum curvature was fixed at 16 degrees, or 359.3 feet radius, and the maximum curve for grade roundings at 3 degrees, or 1910.1 feet radius. A plan and profile of the road are shown in Fig. 1, A, and Fig. 1, B. See Insert.

THE SURVEY.

On April 3, 1889, a start was made for the top of the mountain, with a pack train of thirty burros, loaded with camp equipage and six weeks' supplies, and camp was pitched that night three and a half miles from the top. On the next morning the twelve strongest burros were loaded with the men's blankets and with four days' supplies, and in the middle of the afternoon the abandoned signal station on top of the mountain was reached.

It was feared that we might have trouble from snow, for April is frequently a bad month on Pike's Peak; and we were not disappointed, for it began to snow on the night when the top was reached, and continued for five days without intermission. On the morning of the fifth

day, after a scanty breakfast on the remnants of our supplies, our position being evidently precarious, we improvised sleds out of an old ladder and a dry goods box, and, lashing our blankets to the former and placing our instruments in the latter, we started for camp, three and a half



Shady Spring, from Station 418.

miles below, in a blinding snowstorm, the snow being three feet deep on the level.

Fortunately we had a line of telegraph poles to follow, so that we were in no danger of being lost. At 8 p.m. we reached timber line, a

mile from camp. After building some big fires, all were glad to spread their blankets on the snow and go to sleep. In the morning those who had not taken their boots to bed with them, had great trouble to find them in the foot of snow which had fallen during the night.

About noon of the next day camp was reached, with the instruments in tow, but we had been compelled to leave our blankets where the night was passed. This was our first experience on the location of the Pike's Peak Railway.

Early the next morning a fresh start was made on the location near camp, and it was finished without further mishap. Estimates of cost were made in the latter part of June, but the upper two miles, which were covered with deep snow, were not finally located until August.

The preliminary lines were all platted to a scale of 100 feet to an inch, with 5-foot contours. On this plan the location was projected.

The field work was necessarily slow, owing to the heavy grades used and to the sharp mountain slopes on which the railway was built. The slopes were often steeper than 30° and sometimes reached nearly 45°. In some places if a stone is started rolling, it will continue to roll for nearly a mile. The slopes are frequently covered with fallen timber.

The following are elevations above sea level, in feet:

Summit of Pike's Peak	14,115.32
Highest point on railway	14,087.78*
Lowest " " "	6,570.33
Difference of elevation	7,517.45

The railway is 46,992 feet (8.90 miles) long, measured along the rail, or 46,296.6 feet (8.77 miles) measured horizontally, there being 695.4 feet difference between the sloping and the horizontal distance.

Thé measurements made in the survey called for 46,292.6 feet instead of 46,296.6 feet, an error of four feet. The timber line is 14,700 feet from the top, at an elevation of 11,630 feet, and the highest spring of water along the railway was found 22,000 feet from the top, at an elevation of 10,110 feet.

The average grade is 16.23 per cent. All statements of grades and curves are based on horizontal distances. That is, a 25 per cent. grade means 25 feet vertical in 100 feet horizontal. The actual track distance over 100 feet horizontal, on such a grade is 103.08 feet. 18,576.7 feet, or 40 per cent. of the railway, is on curves. The longest tangent is 3,975.4 feet long. The total curvature on the road is 1844°–48′ (870°-20′ right

*This is the highest elevation reached by any rack railroad yet built, and, so far as I know, there is in operation only one railroad of any description, which reaches a greater elevation, the Puni and Arequipa Railroad, in Peru. This reaches an elevation of 14,660 feet.

and 972°–28′ left). This gives an average of 210 degrees per mile, and is equivalent to a 4 degree curve carried through for the whole distance. The general direction, however, as will be seen by referring to the plan, is good, only one serious deflection from a straight line being made. This deflection was necessary because of the precipitous character of the mountain on the north and east sides, rendering it necessary to approach from the south.

As soon as the estimates were finished, a company was formed, consisting largely of prominent railroad officials in different parts of the country, and contracts were let to W. Hildenbrand, Mr. Abt's representative in the United States, for the rack-rail and fastenings, to the Baldwin Locomotive Works for three engines, to the Wason Manufacturing Company for six cars, and to B. Lantry & Sons for grading and ties. Mr. Hildenbrand was also engaged as consulting engineer.

GRADING.

Ground was first broken on September 25, 1889. Operations were begun near the top, it being necessary to get the upper part of the road finished before the winter snow came, as the contract required the grading to be finished by May 1, 1890. The contractor, however, was forced to leave most of the work above timber line unfinished early in November, because of a snowfall four feet deep, and could not resume operations on this part of the road until the following July. The grading below timber line, including most of the heavy work, which was near the lower end, was finished on time. The contractors had many difficulties to contend with. All tools, powder and supplies had to be got to the work by pack train, as there was no access to the country except by trail. It was difficult to get laborers to work at the high altitudes, but men who staid for two or three weeks became acclimated and could do a good day's work even near the summit. They then seldom left the work. The heavy grades made it impracticable to use teams, and the work was nearly all done with pick and shovel and wheelbarrows.

The frequent snowstorms also gave a great deal of trouble. Pike's Peak is generally free from snow in the latter part of the summer, except in the deep gorges, but near the summit, and two feet below the surface, we found ice which apparently never thawed out.

The price for labor was generally $2 per day. The prices paid for grading were 15 cents per cubic yard for earth, 32 cents for loose rock and 90 cents for solid rock. These prices were much too low, considering the many difficulties to be contended with, and should have been 25 or 30 per cent. higher to leave a reasonable margin for the contractors. The manner of measuring the work, however, favored the contractors somewhat, for the work was paid for both ways; that is, it was

measured in both embankment and excavation, so that if the contractor succeeded in moving a yard of loose rock, for instance, from an excavation into an embankment, he got 32 cents in excavation and 32 cents again in embankment, for the same material. Frequently the material taken out of an excavation very nearly made the embankment alongside of it.

The masonry for four iron bridges, two of 20 feet and two of 30 feet span, was also included in the grading contract, the price for second-class masonry of granite being \$11 per cubic yard. The culverts were all built of red spruce logs hewn on two sides and drift-bolted together.

The total cost of the grading, masonry for bridges and log cul-

CLIMBING SON-OF-A-GUN HILL. STATION 350.

verts, was \$150,900, and this included considerable work that should properly be charged to buildings.

THE TRACK.

The track, see Figs. 2 and 3, is of ordinary 40-pound T rails, laid on wooden ties, at standard gage, 4 feet 8½ inches, with the rack-rail midway between the T-rails. The rack-rail is bipartite, consisting of two rectangular toothed bars of steel, fastened side by side in suitable chairs. The bars are 80 inches long and 4¾ inches deep, and vary from ⅞ inch to 1¼ inches in thickness, according to the grade, ⅞ inch being

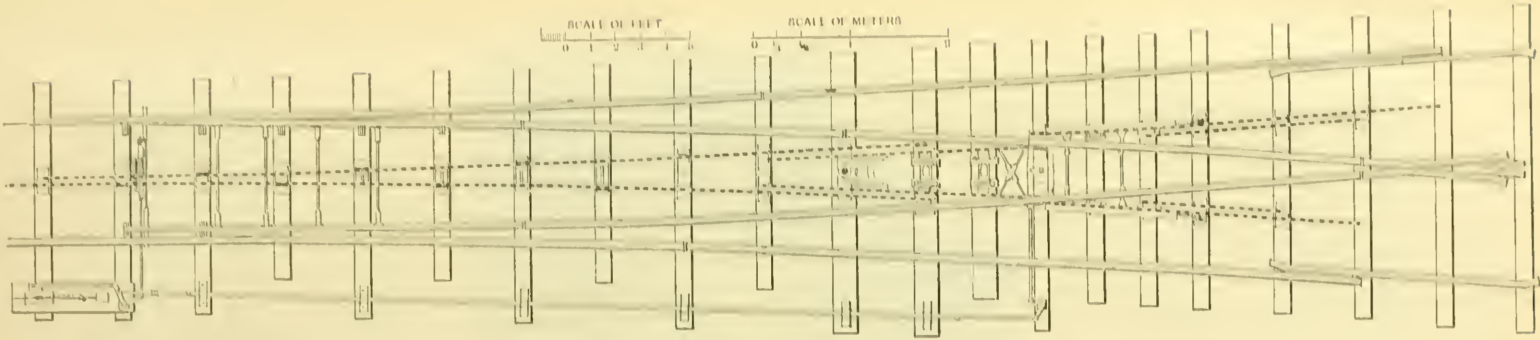
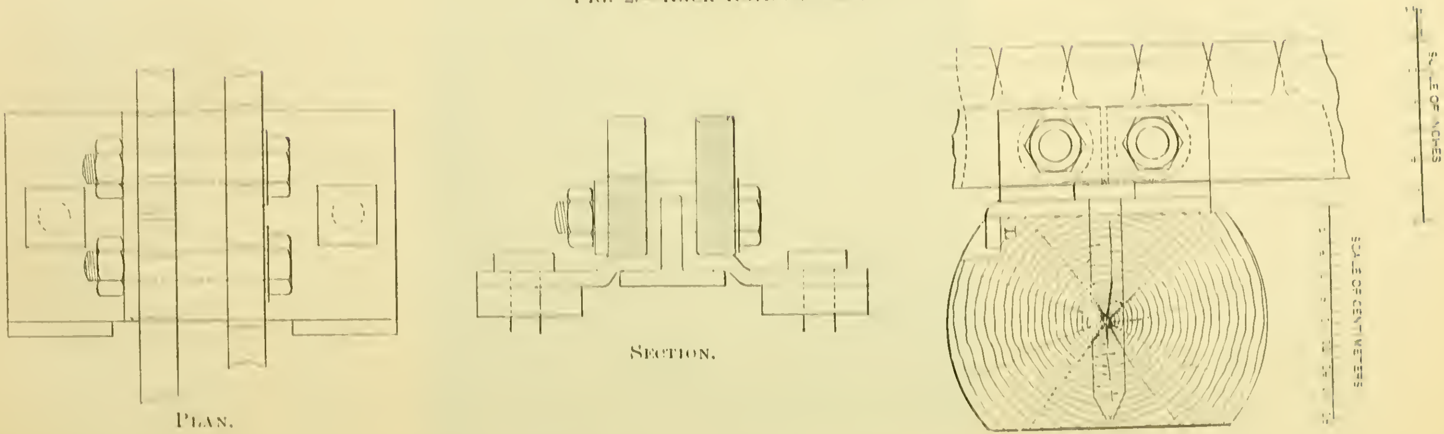


Fig. 2.—Rack-Rail Switch.



Plan. Section. Elevation.

Fig. 3.—Chair and Rack-Rail Fastening.

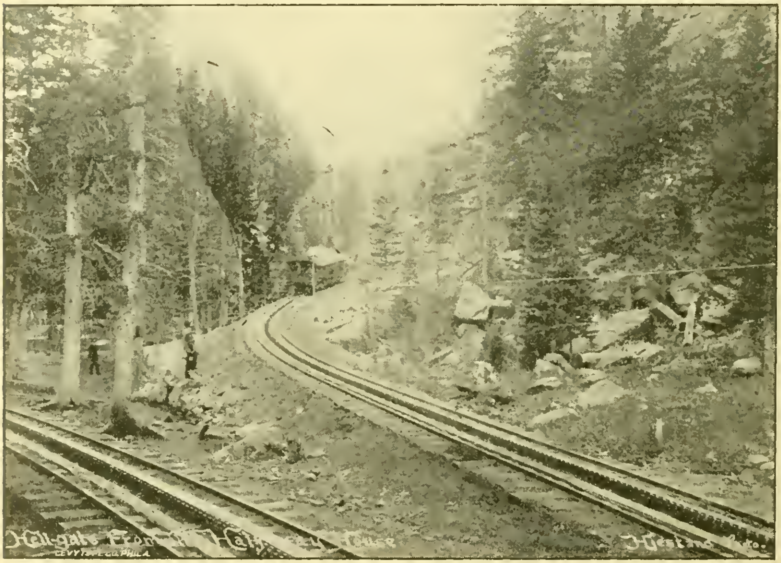
used on all grades under 12½ per cent., 1 inch on 12½ to 15½ per cent., 1⅛ inches on 15½ to 19½ per cent., 1$\frac{3}{16}$ inches on 19½ to 22½ per cent., and 1¼ inches on 22½ to 25 per cent. The pitch distance of the teeth in the bars is 2.35294 inches, and the teeth are 2 inches deep. The specifications for the bars called for steel which would stand a tensile strain of 70,000 pounds per square inch; and a finished bar varying from a templet $\frac{1}{50}$ inch in any part, was rejected. Our inspector remained at the place of manufacture. The ⅞ inch rack-bars, 80 inches long, weigh 72 pounds, and each increase of ⅛ inch in thickness adds 10 pounds to the weight, 1¼ inch bars weighing 102 pounds each. The cost at place of manufacture was 4½ cents per pound.

The chairs, Fig. 3, are of steel, die-forged from a plate ½ inch thick, and have a core of 3½ x 3 inch T iron. They are 13 inches long, 7½ inches wide, and 4½ inches high, 3½ inches of this height being above the surface of the tie, and 1 inch below. The chairs weigh 23½ pounds each. The chairs for ⅞ inch and 1 inch rails are slightly smaller than this, and they weigh 23 pounds. The chairs cost, at place of manufacture, $5.64½ per 100 pounds. The chairs are spaced 40 inches apart, and each has two bolt-holes. These holes are made for ⅞ inch bolts for the ⅞ inch and 1 inch rack-rails, and for 1 inch bolts for the other sizes of rack-rail, $\frac{1}{16}$ inch clearance being allowed in each hole. The rack-bars, being 80 inches long, reach from the middle of one chair to the middle of the second one beyond. They are secured to the chairs at each end by one bolt, and in the middle by two bolts, the bars being arranged so that they break joints. The teeth of one bar also come opposite the spaces in its companion bar. The holes for bolts in the middle of the bars have $\frac{1}{16}$ inch allowed for clearance, the same as in the chairs, but to allow for expansion the hole at each end of each bar is $\frac{1}{10}$ inch larger than the bolt, thus allowing the difference between $\frac{1}{10}$ inch and $\frac{1}{16}$ inch, or $\frac{3}{80}$ inch, for expansion on each 40 inches of bar. Each rack-bar is supposed to be supported mainly by the chair at its middle, and at each end is free to expand or contract. For this reason, I think it was a mistake to allow $\frac{1}{16}$ inch clearance for the bolts in the chairs and in the middle holes of the rack-bars. Our experience showed that $\frac{1}{32}$ inch would have been ample, and there would have been less room for play of the parts. The chairs are secured to the ties by wood-screws, 1 inch x 7½ inches, which weigh 164 pounds per 100. The chairs are further secured by a lug, L, Fig. 3, which projects below the top of the tie.

In addition to the parts described, there is a cover-plate, 7 inches x 2½ inches x ½ inch (or ⅜ inch for the ⅞ inch and 1 inch bars), which goes with each chair, and is placed over the broken joint. These plates weigh respectively 212 and 157 pounds per 100. There are also

spring washers, $2\frac{1}{2}$ inches diameter x $\frac{1}{8}$ inch thick, for each bolt. These washers are of steel and slightly dished, their province being to take up any looseness there might be in the bolts, but unfortunately they took a permanent set when the nuts were screwed home, and did not answer the purpose. Some form of nut-lock would have been preferable.

The $\frac{7}{8}$ inch and 1 inch bolts, used for securing the rack-bars to the chairs, weigh 160 and 223 pounds per 100, respectively. A saving of about $140 per mile was made by using the lighter bolts, chairs, and cover-plates, but this necessitated changing the size of the holes in all the chairs, cover-plates, washers, and anchor-chairs, complicating our



Hell-Gate, from Half-Way House. Station 324. Siding on the Left.

material very much and proving poor economy in the end, for, when we came to track-laying, we usually had plenty of the size we did not want, but were short of some one kind that we required. Only a small part of the material was on the ground when track-laying began.

On most or all of the Abt roads which had been constructed, steel ties had been used, but on the Pike's Peak Railway we used ties of hewn red spruce, 9 feet long by 7 inches x 8 inches. To maintain the proper relative heights of the T rail and rack-rail, it was necessary to frame the chair-ties in some manner, and one side of each was accordingly planed by passing the tie over an ordinary jointer planer, at a cost of about 9 cents per tie.

To prevent the rack-rail from creeping down hill, it was thought necessary to provide anchorages, Fig. 4. These are placed at distances varying with the grade, being 200 feet apart on 25 per cent. grades and 600 feet apart on the lightest grades. One hundred and forty-five in all are used.

From experience on the Pike's Peak Railway the writer considers these anchorages wholly wrong in principle; for, if they do any good at all, they also cause trouble almost as bad as the creeping would be. The rack-bars next above the anchorages crowd together, while those next below them open out. Under these circumstances the pinions on the engines cannot properly interlock with the rack-rail. The aim should be to secure each chair-tie so that it cannot move.

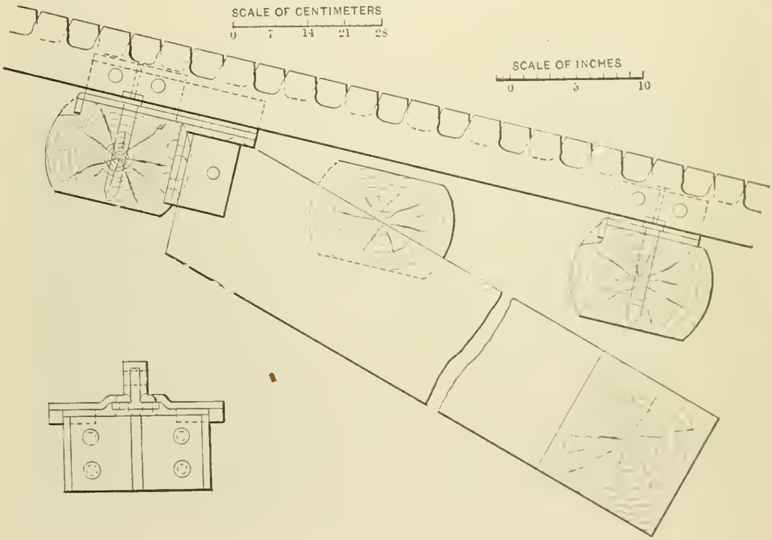


Fig. 4.—Timber Anchorage.

During track-laying the anchorages formed the only provision against the creeping of the rack-rail; and the rack-rail at each anchorage soon began to show serious wear; but early in the following spring, before the road was opened for business, the rack-rail was carefully gaged and adjusted, the chair-ties being removed to where they belonged and 2 inch x 8 inch plank spiked with boat spikes to the chair-ties on each side of the chair, care being taken to have each plank abut against the one below. After this was done the wear of the rack-rail almost entirely ceased.

It may be wise to employ anchorages where the continuity of the rack-rail has been broken, as at switches, or, if the road has both rack and adhesion grades, at the ends of the rack grades.

No provision was made for keeping the smooth rail from creeping down hill, other than the ordinary slotted angle-bars, but the angle-bars were made long enough to allow for six slotted spikes, and no trouble has been experienced from the creeping of the smooth rail.

It was intended to use supported square joints for the smooth rail, the joints to come on a chair-tie; and, in order to accomplish this on curves, rails 29.8 and 30.2 feet long were provided; the difference of 0.4 feet between these lengths being equal to that between the outside and inside rails on 30 feet of center line of a 16-degree curve, the sharpest curvature allowed. On curves of greater radii these long and short rails were used in combination with ordinary 30-foot rails in the required proportions. Thus, on an 8-degree curve half the rails were 30 feet long, one-fourth 29.8 feet and one-fourth 30.2 feet.

The material in a mile of average track, exclusive of anchorages, is as follows:

1,584	Rack-bars, at $87\frac{8}{10}$ lbs.	139,080	
1,584	Chairs, at $23\frac{1}{4}$ lbs.	36,830	
3,168	Rack-rail bolts, at 197 lbs. per 100	6,240	
3,168	Wood-screws, at 164 lbs. per 100	5,200	
1,584	Cover-plates, at 189 lbs. per 100	2,990	
3,168	Spring washers, at $14\frac{6}{10}$ lbs. per 100	460	190,800
352	T-rails, at 400 lbs.	140,800	
352	Pairs angle-bars 38 inches long, at $32\frac{3}{4}$ lbs. .	11,530	
2,112	Bolts for above, 3 inches x $\frac{5}{8}$ inch, at 48 lbs. per 100	1,010	
12,672	Spikes, $5\frac{1}{2}$ inches long, at 55 lbs. per 100 . .	6,970	
			160,310
	Total Iron and Steel		351,110
3,168	Red spruce ties, 7 inches x 8 inches x 9 feet.		

Track laying began June 11, and was finished on October 20, 1890, thirteen months, lacking five days, from the time when the grading was begun.

Our engines allowed us to handle 210 feet of track material to a load, and this material was carefully counted, each load containing the proper number and sizes of rack-bars, chairs, bolts, cover-plates, washers, anchorage material, etc., for the grade we happened to be working on. This material was pushed by the engine as far as the rack-rail was secured, and then loaded on light cars drawn by two mules, a load for the light cars being nine ties and two 30 feet rails on the heavy grades.

To guard against accident from the breaking of traces, etc., the light cars had two stout pieces of oak hinged on behind, these dragged over the ties and prevented the car from running backward. They allowed the mules a chance to rest.

After some experimenting it was found that it was best to keep the

smooth rail several lengths ahead of the rack-rail, nine ties, the number necessary for the chairs for each 30-foot rail, being roughly spaced and the smooth rail gaged and spiked to them.

To space the chairs, Mr. Abt's representative furnished us with wooden patterns, which reached over three chairs and were provided with steel clips and pins fitting the bolt-holes in the chairs. After a very little experimenting the use of these patterns were given up, as it was found that it consumed too much time and did not give good results.

PIKE'S PEAK AND WINDY POINT, FROM PILOT KNOB. STATION 295.

When the pattern was removed in order to put on the rack-bar, we had no means to hold the tie in place except the loose ballast, and this could not be depended on for the absolute exactness required. We then resorted to drift-pins, of $1\frac{1}{2}$ inch steel 10 inches long, 3 inches of which was left as a head to drive on. For 1-inch bolts, $1\frac{1}{8}$ inches of the length was carefully turned to a diameter of $1\frac{1}{16}$ inches, which fitted the expansion holes in the rails, and 3 inches was turned to $1\frac{1}{16}$ inches, which fitted the holes in the chair and the middle holes of the rack-bars. The rest of the length of the drift-pins was tapered to $\frac{3}{8}$ inch.

These drift-pins enabled us to quickly assemble the parts making

up the rack-rail, and took care of the allowance made for expansion. The results obtained, as proved by subsequent measurements, were almost perfect. Their accuracy depended, of course, on careful inspection at the place of manufacture. About twenty of these drift-pins were used at one time, one to each chair. Before the lower one was removed, the bolt was put in the second hole in the chair, and, as soon as the drift-pin was removed, the second bolt was put in.

During August and September there are quite serious electrical disturbances on the Peak, several of the laborers were badly shocked, one of them being confined to the hospital for a month in consequence. Wrench handles, etc., were accordingly insulated by means of rubber hose. The disturbances are seldom, if ever, accompanied by lightning, but the air seems saturated, so to speak, with electricity. The writer remembers being on the Peak one evening when the telegraph wire appeared like a rope of fire, the effect being weird in the extreme.

Track-laying cost $38,100 in all, or about $4,275 per mile. This includes the cost of planing ties, engine service, putting in switches, and everything except engineering. The cost would have been much less had the material been more simply designed.

The switches, Fig. 2, of which there were seven, were placed only on grades not steeper than 12.23 per cent. So far as the bearing rail is concerned, they are similar to the ordinary split switch. When the points of the switch are thrown, four pieces of rack-rail are also thrown at the crossing of the rack and bearing rails. This is accomplished by rods, and a suitable arrangement of levers. For a switch on a 16-degree curve, the rods are 38 feet long. Two of the pieces of rack-rail are thrown close up to one of the bearing rails, making a continuous rack-rail, while the other two pieces are thrown away from the bearing rail, allowing room for the wheel flange and tread of the bearing wheels of the engine and cars to pass.

These switches have worked very satisfactorily. They constitute a great improvement over the old form, where it was necessary to move a section of the bearing rail as well as the rack-rail whenever a switch was thrown. The first five of these switches, complete with ties and bearing rails, cost about $900 each in Johnstown, Pa., but the company has since made several similar switches in its own shop at less than half this cost.

THE ENGINES.

During construction and the first year's operation, the Pike's Peak Railway had three engines built by the Baldwin Locomotive Works. These weighed about 26 tons each, loaded with fuel and water. The cabs and boilers of these engines were much like those of ordinary loco-

motives, but here the resemblance ceased, for the bearing-frame of the engine was inclined, so that the boiler was level on a 16 per cent. grade, the average grade of the road. The engine had no tender, water being carried in two tanks at the side of the boiler, and coal in a box at the rear of the cab, holding one ton. The engine rested on three axles, the forward two being rigidly fastened to the frame, while the rear one was furnished with a radius bar, the rigid wheel-base being 6 feet 8 inches, and the total wheel-base 11 feet 2 inches. To the two forward axles was fastened an inside frame carrying three sets of two pinions each, making six pinions in all. The specifications for these pinions called for hammered crucible steel, with ultimate tensile strength of 100,000 pounds per square inch, stretch 16 per cent. in 8 inches, the teeth to be cut out of the solid disk.

The power from the cylinders, which were 17 inches x 20 inches, was transmitted to a main drum, whose teeth worked in the two rear sets of pinions, the forward set being coupled to the next set by side rods. A further description of these engines will be unnecessary, as they have been entirely remodelled and made over.

It was specified that the engines should push 42,000 pounds, or two loaded passenger coaches up a 25 per cent. grade at three miles an hour, and maintain eight miles an hour on the light grades. This the engines were unable to do, and they also developed many weak points in their construction, the inside frame especially breaking frquently.

At the beginning of the second season of operation, or that of 1892, the company bought a fourth engine, also of the Baldwin Locomotive Works. (See Fig. 5.) This engine resembled the others in appearance, but many important changes were made in the details. The inside frame was done away with, and the pinions were fastened directly to the axles of the bearing wheels, only two sets being used. The main drum also was done away with, and the power was transferred directly from the cylinders to the pinions by means of rocking beams and crank shafts. The first three engines were simple and the fourth compound.

This engine made such a good showing, both in fuel consumption and in time, that it was decided to make over the other three engines, and this was done during the following winter. Before these changes were made it took two hours and twenty-five minutes to make the up-trip, and one hour and thirty-five minutes to come down, but I understand that the up-trip is now made in less than two hours. The fuel consumption during the first season was about 1¼ tons of coal per round trip, but now it is less than a ton. The cylinders of the engines are used as air brakes when coming down the mountain, the valve gear being reversed. Thus the air sucked in by the pistons at each stroke is stored in the steam pipes, and after a few revolutions of the wheels,

the pressure of this air would stop the pistons unless means were provided for letting it off. This is done by means of a pipe leading to the cab, with a suitable valve controlled by the engineer. The wider this valve is opened, the faster is the descent, but if the valve is closed the engine stops almost instantly. In addition to this, the engines are provided with a steam brake, controlled by the engineer and working by a powerful leverage on corrugated collars fastened to the sides of the forward pinions, and with a powerful screw brake controlled by the fireman and working on similar corrugated collars on the rear pinions. Either of these last two brakes suffices to control the train, the screw brake being generally used to make stops at stations.

The method of fastening the tires or cog bands to their centers has

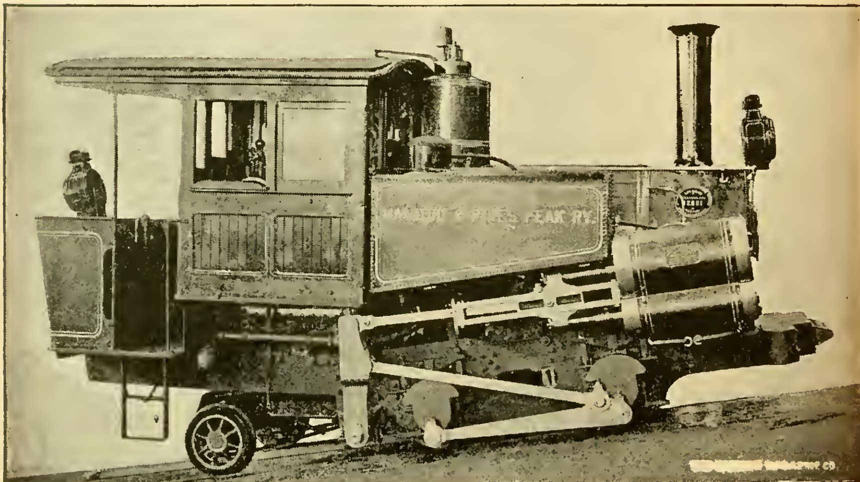


FIG. 5.—BALDWIN LOCOMOTIVE. RECENT TYPE.

a very important bearing on the life of the pinions as well as on that of the rack-rail. Instead of being rigidly fastened or shrunk on the centers, the bands are allowed a possible play of about $\frac{1}{16}$ inch, and this enables the pinions to accommodate themselves to the rack-rail when it is slightly out of adjustment. The work is thus distributed among the pinions instead of being concentrated upon one or two of them.

The pinions of the new engines are so arranged that for every 1.2 inches of forward movement of the engine a different tooth is in full contact with the rack-rail, other teeth being in various stages of contact at the same time. The engines have a total length of 21 feet 2 inches, a total width of 9 feet $\frac{1}{2}$ inch, and a total height of 11 feet 10 inches above the bearing rail.

PLAN AND PROFILE OF MANITOU AND PIKE'S PEAK RAILWAY.

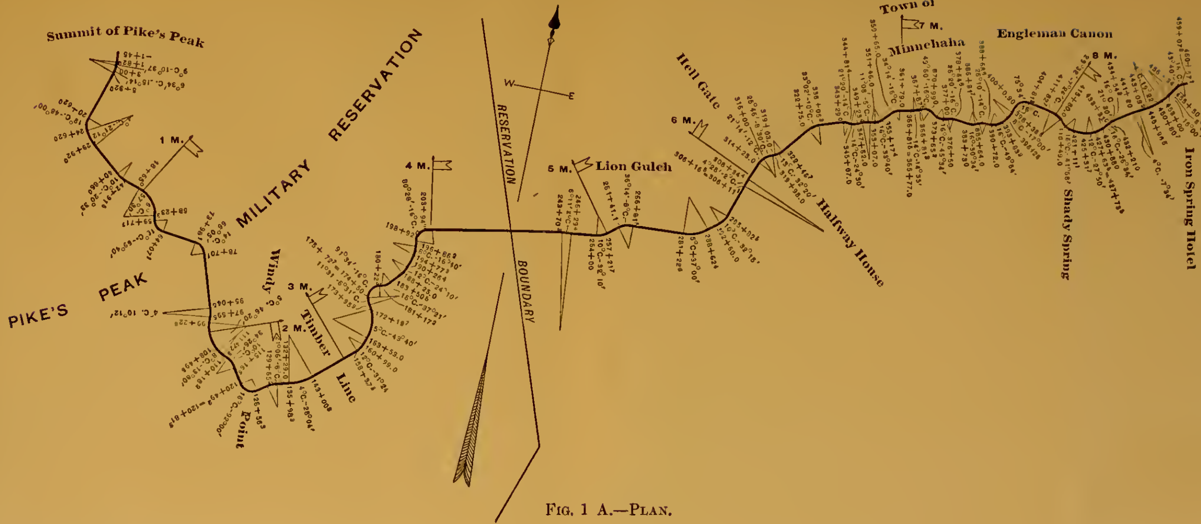


Fig. 1 A.—Plan.

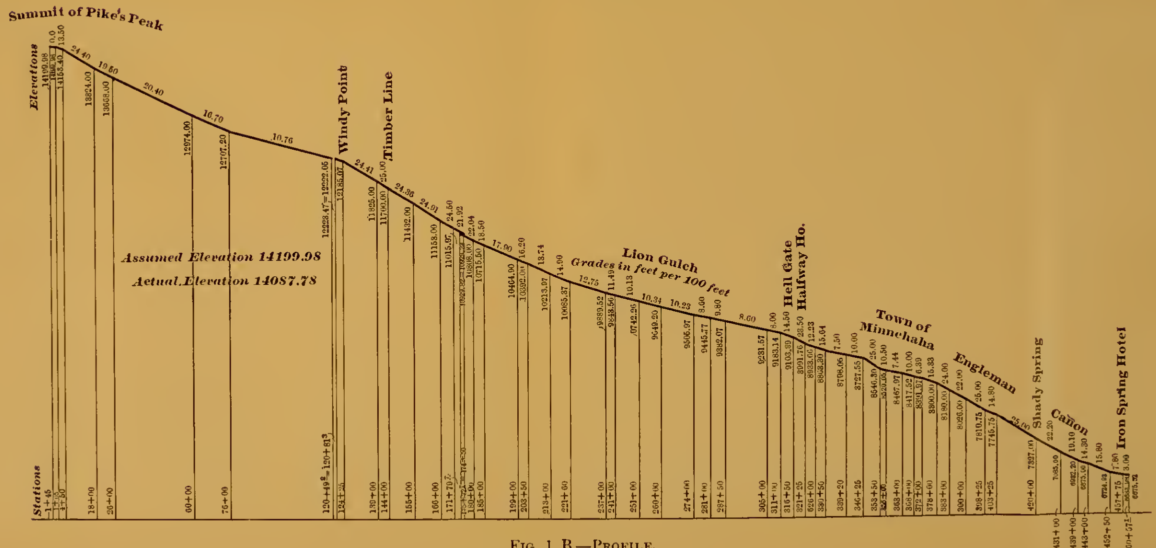


Fig. 1 B.—Profile.

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The engine pushes the car up the mountain and comes down ahead of it. The car is not coupled to the engine, but depends upon its own weight for its motion on the down trip. This accounts for the necessity of setting a minimum limit to the grade. On the down trip no steam is used by the engine, except that required to work the steam brake.

THE CARS.

The cars are much like ordinary passenger coaches, but are built as light as possible, weighing when empty 14,000 pounds. They are 41 feet long over all, 10 feet high and 8 feet 6 inches wide, the floor being 23 inches above the rail. They seat fifty passengers, but sixty-five or seventy are frequently carried on a car. Places on the front platform are eagerly sought for. The floor of the car is parallel to the rail, but the seats are inclined so as to be level on the average grade (16 per cent.). The sides of the car above the seats are made largely of glass in order to give an unobstructed view of the scenery. The cars rest on two axles, each of which carries a pinion brake. The axles are secured rigidly to the car-body, and the bearing wheels are hub wheels, free to turn on their axles. This is rendered necessary by the fact that the pitch line of the brake pinions, which are secured rigidly to the axles, is a constant, while the tread of the bearing wheels is a variable. The wheel base of the cars is 20 feet 5⅞ inches, which is quite long for 16-degree curves, and the fact that the bearing wheels are free to turn on their axles aids materially in getting around the curves. As a still further help, mineral oil is frequently applied to the bearing rails on the sharp curves. The pinion brakes are operated by an ordinary hand-wheel and brake-staff. The chain from the brake-staff connects with a band which works on corrugated collars fastened to the pinions, the pinions being free to roll in the rack-rail, unless the brake is applied. The two pinion brakes have a separate brake-staff on each platform.

The train crew consists of a conductor and one brakeman. The brakeman at all times stands on the front platform with his hand on the wheel ready to apply the brakes at an instant's notice, and on the heavy grades the conductor is required to handle the brakes on the rear platform. The power of the brakes on the cars is such that if necessary the car can be let down from the top of the mountain to the bottom without the engine.

It was the original intention to run trains of two cars, and the specification for the cars specified that they should be strong enough for this purpose. The first trial with a two-car train showed, however, that the lower car could not stand the thrust necessary to push both cars, and one car has since then constituted a train. I doubt very much the wisdom of undertaking to run more then one car to a train on 25 per cent. grades.

WEAR OF RACK-RAIL AND PINIONS.

The life of the rack-rail and that of the pinions on the engine are of course matters of great importance. Before the rack-rail was adjusted, or during construction, some of the rack-rail began to show considerable wear, as did also the engine pinions, but after adjustment the wear of the rack-rail seemed to cease almost entirely, and the pinions showed much less wear than before.

The road has not been operated long enough to admit of forming a reliable estimate as to the life of the rail, but I copy a few paragraphs from a very able paper on Rack Railways, read by Albert Schneider before the American Society of Mechanical Engineers at the Engineering Congress in Chicago, to show what the experience has been in Europe where the Abt rack has been in use for about eight years:

"The contact of the teeth in the Abt gear is almost perfect when new, but becomes absolutely perfect after being in use some time,

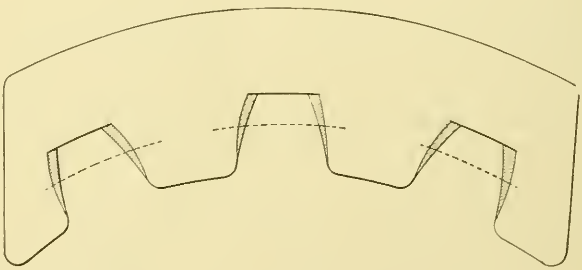


Fig. 6.—Wear of Teeth, Locomotive "Tanne."

because the teeth of the bar wear themselves into shape to correspond to the slightly oblique position of the wheel when passing around curves. After a perfect contact has been reached the wear of the rack-bar teeth practically stops and that of the cogs of the wheel is very small.

"With the present traffic on the Hartz railway, according to my observation and calculation, the rack-teeth will wear 0.04 inch in 150 years, while the cog-wheels will last twelve years before being worn out.

"Fig. 6, shows the wear of a tooth of the locomotive 'Tanne' after having been in operation eight years. It is, of course, evident that the wear in the first years, before the teeth have adapted themselves to the rack-teeth, is greater than in subsequent years, hence the wear in the first eight years must necessarily be more than half the admissible wear."

The following are the statistics of wear of these teeth :

WEAR AT THE PITCH LINE:

Original thickness of tooth .	$2\frac{3}{16}$ inches.	*a.* On each side of the tooth . .	$\frac{7}{32}$ inch.
Present thickness of tooth . .	$1\frac{3}{4}$ "	*b.* Total wear	$\frac{11}{32}$ "
		c. Admissible wear on each side	$\frac{5}{16}$ "
Wear per year	$\frac{1}{16}$ inch.	*d.* Admissible total wear . . .	$\frac{5}{8}$ "
Distance run	68,380 miles.	Wear per 10,000 miles	$\frac{1}{16}$ "

The Hartz Railway is a mixed rack and adhesion road, which uses 6 per cent. maximum on rack-rail and $2\frac{1}{2}$ per cent. on adhesion grades. It does a mixed freight and passenger business and is operated the whole year.

ABOVE TIMBER LINE. STATION 32.

Up to the present time nineteen railways using the Abt system are in operation, with a total length of 207.55 miles, of which 105.77 miles are supplied with rack-rail. Fourteen of these railways are in Europe, two in South America, one in Japan, one in the West Indies, and one, the Manitou and Pike's Peak Railway, in the United States. In addition to this, twenty-six railways using the "Ladder" or Marsh rack have been built. These have a total length of 100.59 miles, partly rack and partly adhesion, of which twenty-one are in Europe, two in Brazil, one in Sumatra and two in the United States, viz., the Mt. Washington Railway and the Mt. Desert Railway.

MASONRY LINING AT MULLAN TUNNEL.

By H. C. Relf, Member of the Montana Society of Civil Engineers.

[Read February 10, 1894.]

The Mullan Tunnel is located on the main line of the Northern Pacific Railroad, twenty milles west of Helena, at the crossing of the main range of the Rocky Mountains.

The summit on line of tunnel reaches an altitude of 5,855 feet above sea level. The tunnel is 3,850 feet long, on a tangent throughout the grade, going west, ascends 105.6 feet to the mile, or 2 per cent. The summit of grade is 400 feet beyond the west portal, and its elevation is 5,548 feet above sea level.

Ever since its completion in the fall of 1883, this tunnel has been a menace to the successful operation of the road, owing to the treacherous character of the material through which it was driven. Traffic has several times been stopped by "cave-ins" and "burn-outs," at one time so serious as to demand the temporary restoration of the "overhead line," which was used for a time before the final completion of the tunnel.

This fact, together with the perishable nature of the timber lining, induced the management to start the work of permanent lining in time to avoid any necessity for undue haste in its prosecution, and also to distribute the expense over a greater length of time.

Although the matter was under consideration in 1891, it was not until July, 1892, that work on the plant commenced, and it was two months later when active operations in the tunnel were begun.

The material encountered in the tunnel is mostly of a syenite formation, interspersed with granite bowlders and streaks of clay, through which there is a considerable seepage of water. This necessitated the timbering of a large portion of the tunnel at the time of construction, and more timber was added from time to time by the operating department, until, when this work was started, nearly three thousand feet had been timbered.

Where falls had occurred, or where there were indications of excessive pressure, close timbering was used, and in some cases the tunnel section had been decreased by placing duplicate sets of timber inside the original set; thus materially increasing the cost of removal for permanent work.

The original timbering, Figs. 1, 2 and 5, consisted of sets spaced four feet centers with 12 inch x 12 inch posts *P*, supporting wall-plates,

Figs. 1 and 5, and a five-segment arch of 12 inch x 12 inch timbers joined by ½ inch dowels. The arch was covered with 4 inch lagging, Fig. 5. The space between the lagging and the roof was filled with cord-wood, supported by 4 inch x 12 inch headers, *H*, Fig. 5.

Where the overhead pressure was excessive and where it was

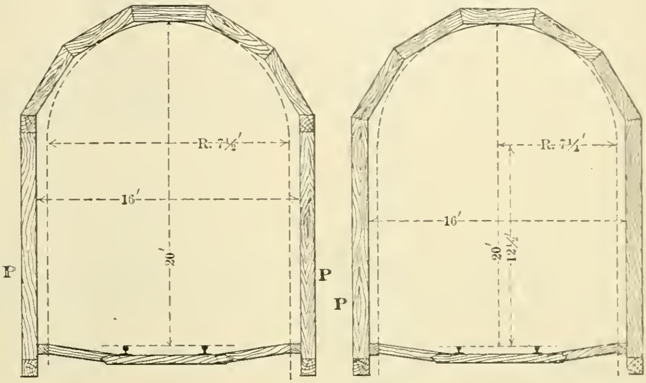


FIG. 1.—WITH WALL-PLATES. FIG. 2.—WITHOUT WALL-PLATES.
PRESENT TIMBER SECTIONS. SCALE 1=144.

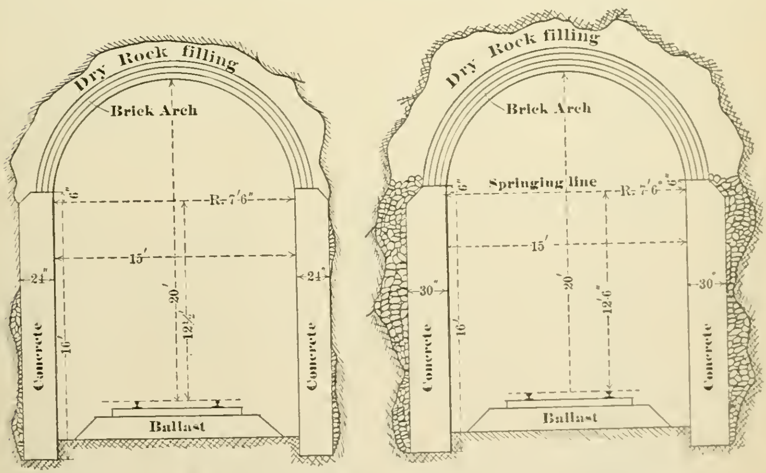


FIG. 3.—MINIMUM SECTION. FIG. 4.—AVERAGE SECTION.
PERMANENT WORK. SCALE 1=144.

necessary to repair breaks caused by falls, the wall-plates were dispensed with and the crow-foot segment came directly in contact with the post, Fig. 2. This character of timbering is more difficult to remove than that shown in Fig. 1. Except where reduced by timbering placed inside the original sets, the clear width was made 16 feet and the clear

height 20 feet above top of rail. The dotted lines indicate the dimensions of the permanent section.

Figs. 3 and 4 show the permanent section adopted, the clear width being reducèd to 15 feet, while the height remains 20 feet. The side walls are composed of concrete up to a point six inches above the springing line of a semi-circular arch built of brick. This required the removal of all of the original timbering.

The plant for this work is located near the west end of the tunnel. It comprises the necessary tracks, toolhouses, blacksmith-shop, boarding-house, water-tank and a cement-shed, capable of storing 5,000 barrels.

In the east end of the cement-shed, is a sand-bin and engine-room, the latter containing a 15 horse-power engine, which runs a dry cement-mixer. This mixer consists of a spiral on an 8 foot shaft running in a trough. The action of the spiral carries the dry cement and sand from a hopper at one end (mixing it meanwhile) to a chute at the other. The latter deposits the product on top of a staging car, to be mixed with water as required for mortar.

The mortar consists of 1 part English Portland cement to 3 parts sand. Alternate layers of cement and of sand, in the proper quantities, are placed upon the floor alongside of the hopper of the cement mixer, into which they are shoveled after being roughly mixed by shovelers.

The rock for the concrete is obtained from a slide of broken quartzite twenty miles west of the tunnel, and requires very little extra breaking to make the size suitable for the work. The stone is carried on an ordinary flat car, which, with one of the cement cars, completes the outfit necessary for work on the side walls.

The drawings for the remaining figures were prepared for the Stampede Tunnel work, which has been under way since 1889, and due credit must be given Mr. Andrew Gibson, the engineer in charge, for their perfection. The Mullan Tunnel work being identically the same, with the exception of a slight difference of size in cross-section, the same drawings suffice for its illustration.

Figs. 5, 6 and 7 show the manner of removing the timber and building the concrete side walls.

A 7 foot section *AB* of the wall, Figs. 6 and 7, is first prepared by removing one post, with the lagging and cord-wood filling, if any, behind it, the arch being supported by struts *SS*, Fig. 6, from the remaining posts to the wall-plate, or, where there is no wall-plate, to the crow-foot segment on either side.

After removing any loose material, and excavating from $2\frac{1}{2}$ to 3 feet below top of rail, two false posts *FF*, Figs. 5, 6, and 7, of 8 x 10 timbers are set at the proper distance from the center line, and the top of

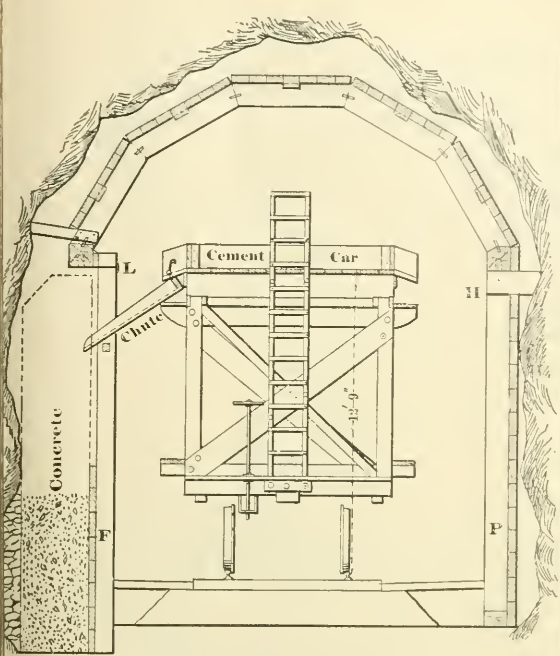
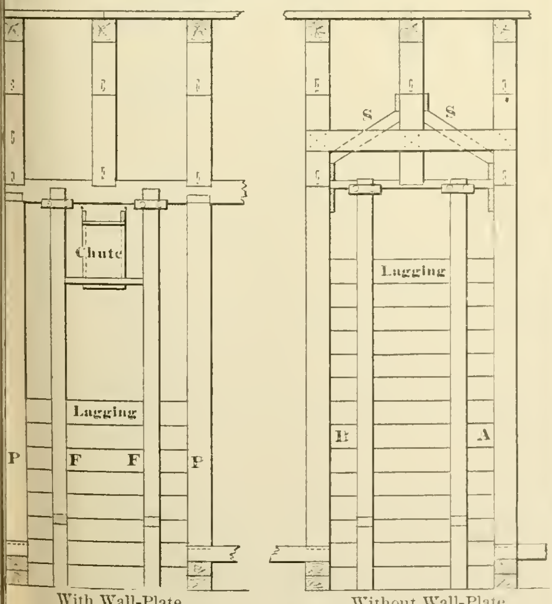


FIG. 5.—SECTION, WITH CONCRETE CAR.
SCALE 1=96.



With Wall-Plate. Without Wall-Plate.

FIG. 6.—LONGITUDINAL SECTIONS.
SCALE 1=96.

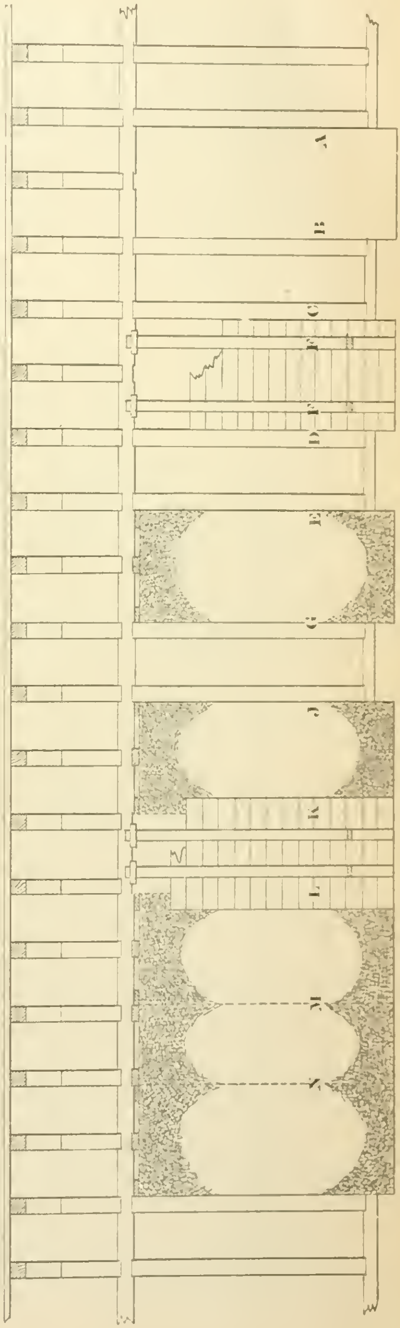


FIG. 7.—METHOD OF WALLING UNDER WALL-PLATE. SCALE 1=144.

each of these is held in place by means of "*L*" bolts *L*, Fig. 5, fastened to the wall-plate, or by a 4 inch x 12 inch header, which is introduced where there is no wall-plate. Two-inch planks are then placed behind these posts, and held in position by means of wedges between the plank and the old posts remaining on each side. The full height is not planked up at once, but only as required. A number of these 7 foot sections are prepared in this way—a 5 foot section of timber wall being left between each two, and they are then ready for concrete.

In Fig. 7

A B	represents	1st	series,	7	foot	section	No. 1, posts removed.
C D	"	1st	"	7	"	"	No. 2, ready for concrete.
E G	"	1st	"	7	"	"	No. 3, completed.
G J	"	2d	"	5	"	"	No. 1, before removing timber.
J K	"	1st	"	7	"	"	No. 3, completed.
K L	"	2d	"	5	"	"	No. 2, ready for concrete.
M N	"	2d	"	5	"	"	No. 3, completing wall.

Fig. 5 shows a section of the tunnel with this work under way. Sufficient mortar to make an 8 inch layer of concrete is first run into the section by means of the chute from top of car. The intention is to use five parts rock to one part cement and three of sand. The mortar car is then moved to another section, and rock from the flat car in attendance is shoveled into the first section until it takes up all the mortar.

This operation is repeated at several sections before returning to the first one, which by this time is ready for a second layer, and in this manner the wall is carried up to the proper height.

Should the original excavation allow for more than 30 inches of wall, a back mold is used and the space behind is filled with dry rock carried up simultaneously with the cement, Figs. 3, 4 and 5.

After twenty-four hours the wall is hard enough to stand the removal of the lagging for use at other sections, and in from ten to fourteen days is sufficiently strong to hold the arch, which is then transferred to it by blocking up under the wall-plate or crow-foot segment. The intermediate 5 foot sections are then ready for similar treatment.

By December, 1892, 1,000 lineal feet of side-wall were completed, and the work was then closed down for the winter. It was resumed in May, 1893, and continued until August 12th of the same year, 2,140 feet of side-wall being built during this time, making a total of 1,570 lineal feet of tunnel up to that date.

The average progress per working day was 30 lineal feet of side-wall, containing 45 cubic yards of concrete, making an average of 3 cubic yards of concrete per lineal foot of tunnel. The average cost per cubic yard was less than $8.00, including all labor required in removal of timber, work train service, lights and tools, engineering and superintendence, and interest on plant.

On September 15, 1893, the work of arching commenced. It is still in progress and 950 feet have been completed.

The centering used is shown in Fig. 8. There are four ribs in each set, spaced 3 feet, center to center. Upon these ribs 4 inches x 4 inches lagging is laid in 3 feet lengths. Each rib is strengthened by the use of iron angle plates on the inner sides of the joints and a continuous length of 4 inches x $\frac{3}{8}$ inch band iron on the outside. Three-inch jack-screws are used to raise or lower the center, and timber dolleys for moving it longitudinally. A length of from 3 to 9 feet of arch is put in at one time, the length depending upon the nature of the ground.

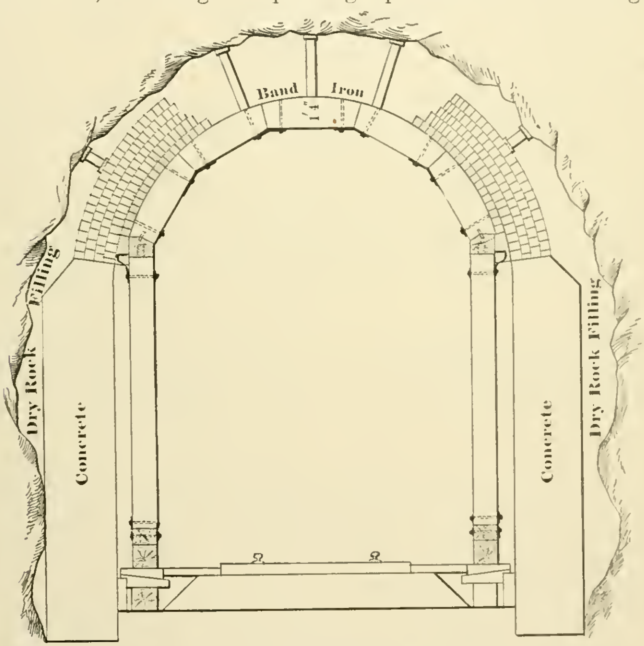


FIG. 8.—CENTER, WITH BRICKWORK NEARING COMPLETION.
SCALE 1=96.

The old timbering is generally removed by putting a small charge of giant powder in one of the segments after partially cutting through it. The resulting débris of timber, cord-wood and loose rock is caught by a strongly constructed car placed directly underneath. The top of this car is 12 feet 6 inches above top of rail. The space between the side of this car and the wall of the tunnel is covered with heavy planking, so that nothing can drop below. After this débris is removed by loading it on to another car in attendance, the center is moved ahead and raised to the proper height for the brickwork, and timber props are placed on the ribs where necessary to keep loose material from coming down.

The section is now ready for the bricklayers, who use two high staging cars similar in construction to the cement car shown in Fig. 5. One car is supplied with dry cement mortar in the same manner as for concrete and in the same proportions, and the other with brick. The bricks for the work are made at the yards of Jacob Switzer and the Mullan Pass Coal Co. near the tunnel, and are of most excellent quality. The size is 2½ inches x 4½ inches x 9 inches. These bricks cost more per thousand than bricks of the usual size, but fewer of them are required for a cubic yard. They therefore cost less per cubic yard for laying, so that they are in the end more economical for the work.

Four rings have so far been used, laid in row locks, and the space between extrados of arch and roof is filled with dry rock. Two gangs, of three bricklayers and six helpers each, are employed, and the present progress is 12 feet per day, or rather per night, for all work in the tunnel is now done between the hours of 7 P.M. and 6 A.M., there being fewer trains during these hours than through the day.

The brickwork is carried up uniformly on each side to the crown as shown in Fig. 8, the roof props being transferred from the ribs to the completed brickwork, as it is advanced, and dry rock filled above the arch.

The four rings of large brick make an arch 20 inches thick, giving 1.62 cubic yards of brickwork per lineal foot of tunnel. This costs at present about $17.00 per cubic yard, or $27.50 per lineal foot of tunnel.

The total cost of the work to date will average about $50.00 per lineal foot of tunnel, and this will probably be decreased this season.

No plan for the portal has, as yet, been decided upon, as this is the last work to be done, and it will require about eighteen months to complete the side walls and arch.

All the work is done by the Company's forces, directly under the assistant engineer in charge, Mr. F. J. Taylor, to whose careful and efficient supervision its success is due.

THE MANCHESTER SHIP CANAL.

By John Dean, Member of the Engineers' Club of St. Louis.

[Read February 21, 1894.]

I. THE INCEPTION OF THE SCHEME, AND PROCURING THE CHARTER.

For years there has been talk of improving the rivers Mersey and Irwell, so as to make them navigable for large shipping right up to Manchester. The traffic between Manchester and Liverpool had grown to such enormous proportions that four railroads, one of them having four tracks most of the distance, had been successively built between the two cities. The railroad charges combined with the Liverpool dock dues, were so excessive as to constitute a very heavy tax on the freight to and from Manchester and the surrounding district, and at last Manchester was compelled to find relief from these heavy charges, or have her commercial supremacy wrested from her, for the margin of profit was growing smaller, year by year.

In the year 1882, Mr. Adamson got together an influential committee of wealthy merchants who formed themselves into a company, subscribed a good round sum and employed two well-known engineers to survey the route and formulate a plan for the canal, and to prepare detailed estimates of the work.

Mr. Hamilton Fulton prepared plans for a tidal canal, and Mr. Leader Williams, on the other hand, proposed a lock canal, and his plan. After consulting Mr. Abernethy, one of the most eminent consulting engineers in the country, the committee adopted Mr. Williams' plan for a canal with locks.

The application to Parliament for a charter caused one of the bitterest parliamentary fights on record. All the railroads running between Manchester and Liverpool, the Liverpool Dock Board and merchants, and a large array of landowners, all joined forces to defeat the bill.

When it is desired to obtain a charter for any public work in England, accurate surveys have to be made, and maps must be prepared and presented before committees of the House of Commons and of Lords. Five per cent. of the estimated cost must be deposited as a guaranty of good faith. Every landholder or corporation whose property is touched or affected, receives notice stating what property the company proposes to take. Anyone thinking himself injured in any way by the enterprise has the right to oppose the bill in committee or to demand compensation.

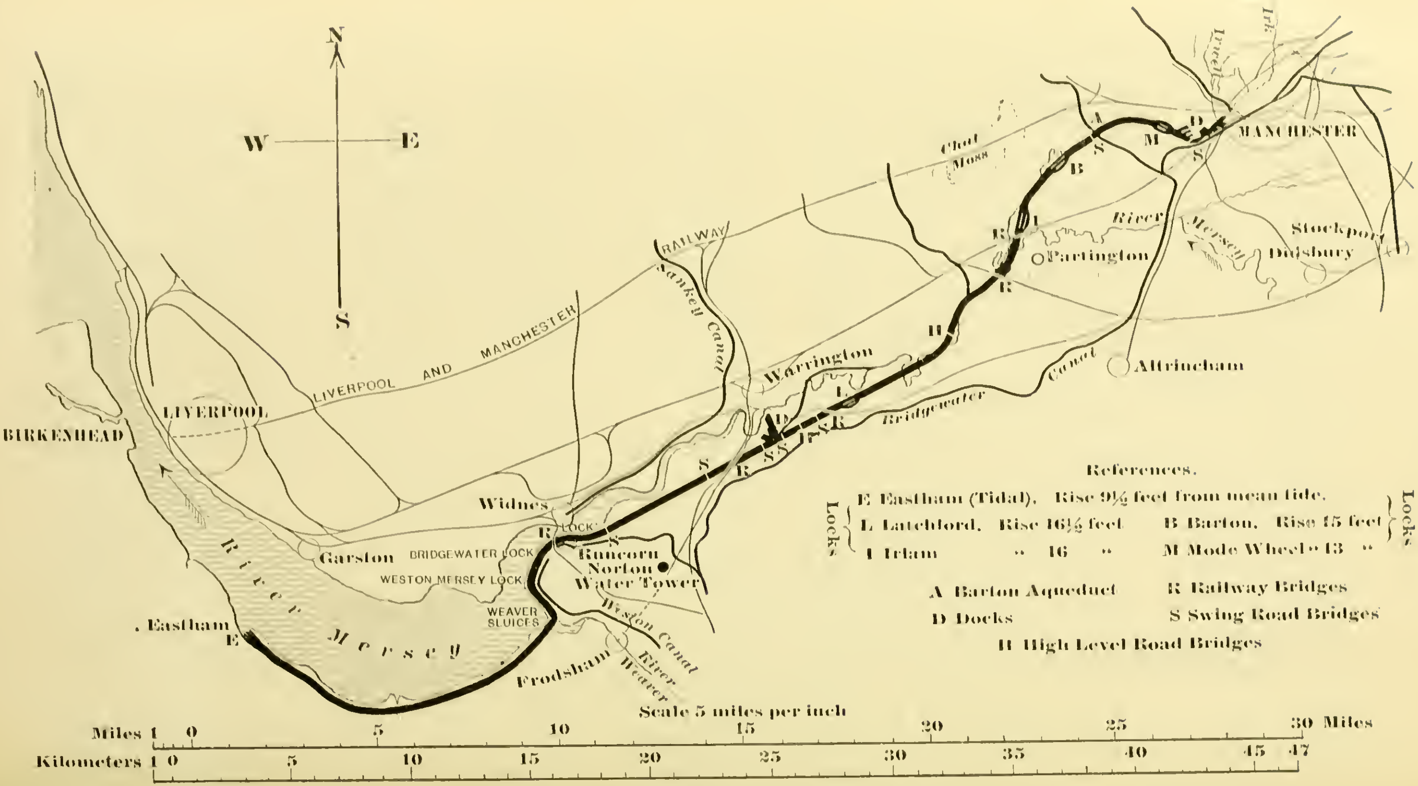


FIG. 1.—MANCHESTER SHIP CANAL. PLAN.

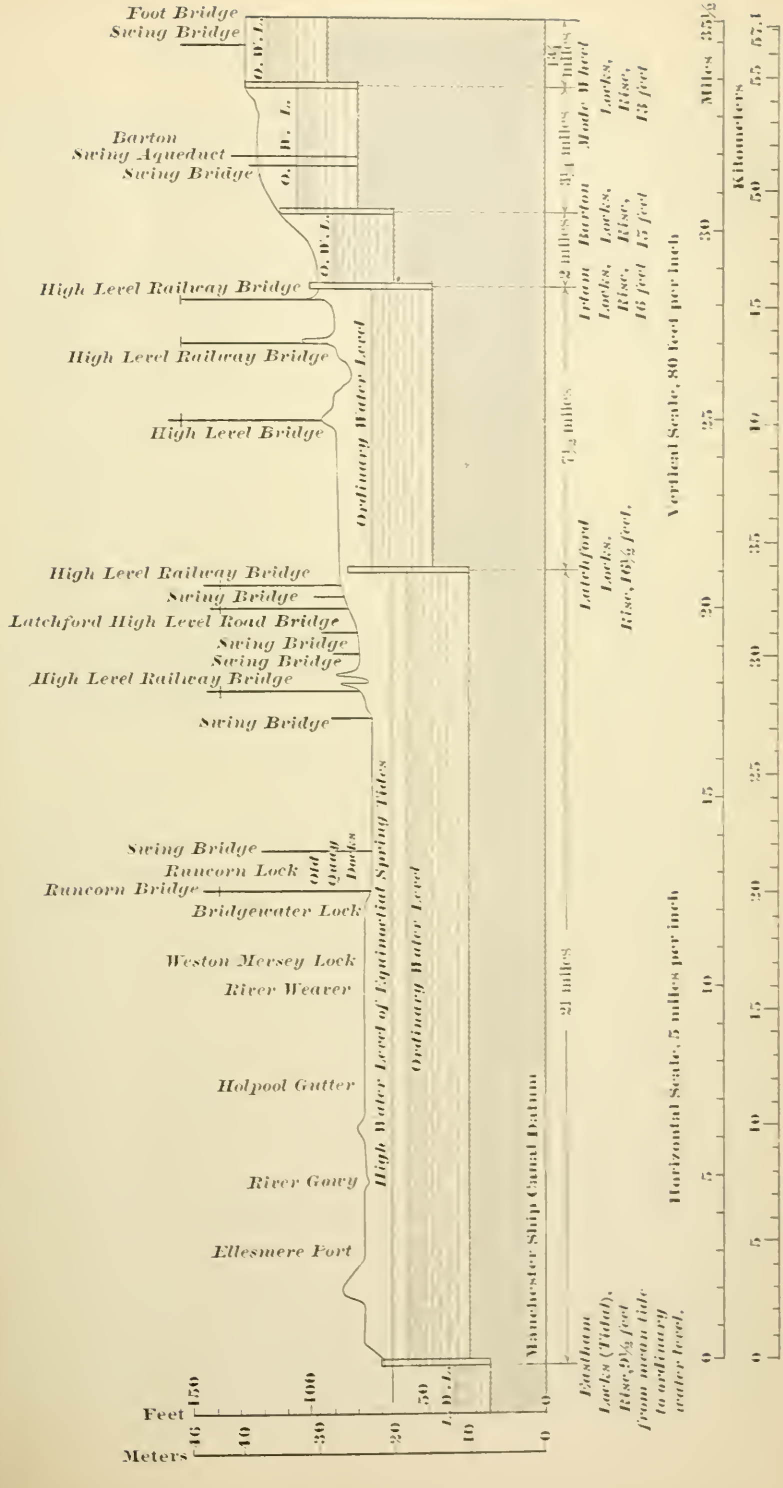


FIG. 2.—MANCHESTER SHIP CANAL. PROFILE.

The enterprise must be proven to be necessary for public interest, and not a mere duplicating of an existing work. The promoters of the Ship Canal were required to prove the amount of the traffic of Manchester and its surrounding towns with the seaboard, and to show that the existing rates of freight could be reduced by the canal and that there was enough traffic in sight to support the new undertaking.

For two successive years the charter was refused, mainly on the ground that the estuary of the Mersey would be disturbed and injured by the construction of the canal; but in the year 1885, on the third application, the act was finally passed, but not before nearly two million dollars had been expended in surveys and in parliamentary expenses.

In granting the charter, Parliament had enacted that the Ship Canal Company should purchase the property of the old Bridgewater Navigation Company, which owned the right to navigate the Mersey. On this work the company had expended large sums of money, and it also owned the Bridgewater canal, a barge canal about 6 feet deep by 30 feet wide, operated mostly by steam tugs, and running from Manchester to near Liverpool and also to the Worsley coal mines. This canal at one time had been an important factor in keeping down the freight charges of the railways, but the latter had for some years pooled with the navigation company, with the result that the canal rates had been advanced to an equality with those charged by the railroads.

This ship canal company paid $8,000,000 for the Bridgewater Canal Company's property, which already earns sufficient income to pay the interest and all expenses. The original estimate of the cost of the whole canal was $50,000,000; but a variety of causes brought the total cost to the enormous sum of over $70,000,000. A large landholder near Manchester, who had been one of the bitterest opponents of the scheme, died soon after the act was passed. His son, who was more friendly to the scheme, offered to sell to the ship canal company the additional land required to make a great enlargement in the proposed Salford docks. His offer was accepted, and as a result those docks are now twice as large as contemplated by the original plans. A large portion of the excess of cost over the estimate must be credited to this item.

Again, in order to save excessive damages for severance of properties, the ship canal company has had to buy large tracts of land in excess of their actual requirements. This, however, owing to its proximity to the canal, may be expected to yield a handsome return in the near future. The railroads have also exacted from the ship canal company heavy sums as compensation for operating the grades required for crossing the canal. Thus, the London and Northwestern Railway Company was paid over $500,000 to vacate its old roadbed and use the high bridge at Latchford, and a large additional sum had to be set aside, to

be paid to the railway company, if it concludes to make its road four-tracked within the next two years.

A heavy item of construction, which could not be closely estimated, was the cost of the long sea-wall, carrying the canal along the edge of the Mersey estuary, from Runcorn to Eastham, for in places this is carried over treacherous sand banks. At one time, after $50,000,000 had been spent, the whole undertaking seemed as if it would be wrecked for lack of further funds; but the corporation of Manchester, with rare public spirit, realizing the importance of the canal to the city, took the matter in hand, and, by issuing $25,000,000 of bonds, provided for the completion of the work, at the same time securing the control of the canal, until its bonds were repaid.

This action is in striking contrast with the apathy of our government towards the Nicaragua ship canal.

II. PROMINENT ENGINEERING FEATURES.

Manchester is situated in the Irwell valley, about 35 miles inland, in an easterly direction from Liverpool, and its elevation is about 60 feet greater than that of mean high water level at Liverpool; but the rivers Mersey and Irwell had a fall of but a little over 1 foot to the mile, between Manchester and Liverpool, for the distance, following the old course of the rivers, was over 50 miles.

By straightening out the old channel in places, and by following the valley, near the rivers, the rest of the way, a good even profile and cut were obtained, and the distance by the ship canal was reduced to 35½ miles. The deepest cutting is near Runcorn, where, for a short distance, it reaches 66 feet. The average depth of cut is about 36 feet. The largest cutting is at Latchford, where, for 1½ miles, the depth averages 55 feet. The total amount of excavation was nearly 53,000,000 cubic yards, of which over 12,000,000 yards were solid rock.

The excavation was mostly through alluvial deposits of loam, clay, gravel and sand, generally overlying the rock. The rock is a red sandstone, almost precisely like our Lake Superior sandstone, and hardens on exposure.

The canal, as originally designed by Mr. Leader Williams, ended near Runcorn, from which point a channel was to be dredged across the estuary of the Mersey, and kept in place by training walls, between which the channel was expected to keep itself open.

The Liverpool Dock Board, however, strongly opposed this part of the plan, and brought Mr. Eads over to England to sustain its position. His evidence so strongly impressed the parliamentary committee that it rejected the bill on account of this feature. Mr. Eads urged that the canal be carried down to deep water in the estuary, along the south

bank of the Mersey, and the present location of the canal, from Runcorn to Eastham, was accordingly adopted. Beginning at Eastham, and traveling up the canal, we note the following prominent features.

The entrance to the ship canal at Eastham is by three locks, one 600 feet long x 80 feet wide, one 350 feet x 50 feet, and the third 150 feet x 30 feet. In addition there are two large sluices 20 feet wide, which assist in filling the canal, as well as in carrying off any flood water from it.

These are all opened when the tide in the estuary reaches the level of the water in the canal, and as this level is maintained only at mean high water, it will be seen that, except for a few days in the year, these locks will be open for a considerable time both before and after high water, so that much of the shipping will be able to enter the canal without having to use these gates.

Large dredges have been at work on the approach to the canal from the estuary at Eastham, and on the first of this year, when the canal was opened, the depth at this point was already so great, and the low water depth of the Mersey at the Liverpool docks so shallow, that at some tides ships could reach Manchester by the canal earlier than they could enter the Liverpool docks.

The depth of water in the canal is 26 feet, while that on the lock sills is made 28 feet, in order to allow for future deepening of the canal if necessary. This depth will admit the largest ships built at the present time.

The width of the canal from Eastham to the Barton locks is 120 feet at bottom and 172 feet at the water level. From Barton to the end of the canal at Manchester it is 170 feet at bottom and 230 feet at the water level, so that the largest ships can easily pass through any portion of the canal.

The following are the depths and the bottom widths of several important ship canals:

	Manchester.	Suez.	Welland.	Amsterdam.
Depth, feet	26	26	13	23
Bottom width, feet . . .	120-170	72*	100	89

All the lock and sluice gates are of Demarara greenheart. They are built on the best scientific lines and equipped with the latest hydraulic machinery. The time actually occupied by a ship passing through the largest lock from one level to the next higher, is only eleven minutes, including the closing of the lower gate, raising the level of the water in the lock about 15 feet, and opening the higher gate. The weight of each leaf of these large lock gates is nearly 300 tons.

* With occasional wider places for passing.

From Eastham to Runcorn the canal is built on the southern bank of the estuary, and the sea wall forming the northern side of the canal was made exceptionally strong, in order to withstand the terrible storms that sometimes rage in the estuary In several long stretches, the canal is built out in the estuary, sometimes across the old channel of the Mersey, or over treacherous sand banks. In these cases the canal had to be largely supported on piling. The sea wall and the canal are here constructed of concrete. The sea wall is 16 feet wide on top, and protected by closely driven piling.

This was extremely tedious work and required the greatest engineering skill to overcome the various obstacles encountered. Where the river Gowy, which we should call a creek, entered the estuary, the ship canal company was compelled by the Liverpool Dock Board to build sluices, at a very heavy expense, so as to keep open the old channel in the estuary. This was a useless piece of work, but had to be carried out in order to comply with the charter.

At Ellesmere Port the Shropshire Union canal empties into the ship canal, and a large dock has been constructed with over half a mile of quay front.

The river Weaver enters the canal at Saltport, which, by the way, had no existence until the canal was built, but which is already quite a port and an important and growing town.

The Weaver Navigation has, for a long time, been an important waterway, penetrating to Nantwich and the salt district, and has carried a large traffic. By backing up the Weaver to the level of the canal, a large pool has been created, and this is being largely used for a timber pond. Large docks and locks have also been constructed, and these produce a much larger revenue than was expected so soon.

Another important piece of engineering was constructed here, viz., ten large sluice gates, with a capacity of 3,000,000 cubic feet per minute, to allow the flood waters of the Weaver to escape into the Mersey. This flood water is carried under the ship canal in huge siphons.

At Weston Mersey, the Bridgewater canal, now the property of the ship canal company, enters the ship canal through a large lock. At Runcorn a large dock has been created for the local traffic.

Near Runcorn, the canal passes under the immense viaduct that carries the Liverpool and London line of the London and Northwestern Railway over the river Mersey. The clear head-room from the water level in the canal to the lower side of all bridges is 75 feet. This distance was fixed by the height of the Runcorn viaduct, above the Mersey mean level.

The two piers that carried the span of this viaduct over the Bridgewater canal, had to be underpinned and carried down more than 20 feet

lower. Any engineer, who has had experience in this kind of work, can appreciate the labor and care involved in underpinning these tall piers, which carried a double-track railroad, with a heavy traffic constantly passing.

West of Runcorn, the canal encountered the Vyrnwy aqueduct, which carries the water-supply of Liverpool from Lake Vyrnwy.

The aqueduct was conveyed under the canal by means of a large siphon.

At Warrington, two railroads had to be carried over the ship canal, viz., the main line of the London and Northwestern Railway, from London to Scotland, and the Great Western Railway. Deviations, with long and easy double-track approaches, about 1¼ miles long on each side of the canal, were built for all railroad crossings, and long, through spans, in one instance 270 feet clear, had to be erected, as in some cases the railroads cross the canal at a considerable skew, the minimum opening being 125 feet, at right angles to the canal.

At Warrington, the ship canal just touches one of the bends of the old river channel, and the old bed will be utilized for docks as soon as possible. At the present time, a considerable amount of dock room has been provided for immediate use, partly by widening the canal, and making its sides vertical.

This practice has been carried out at several convenient points, to provide for the possible needs of the future.

At Latchford, another branch of the London and Northwestern Railway is carried across the canal.

At this place, which is a little more than 20 miles from the entrance to the canal at Eastham, we arrive at the end of the tidal reach and pass through a pair of parallel locks, having a lift of fifteen feet. One of these locks is 600 feet x 65 feet, and the other 550 feet x 45 feet. There are also three pairs of floodgates, so that when there is a flood greater than the canal can carry off, part of the surplus water can be turned into the old river-bed, and thence carried to the estuary.

From Runcorn to this point the ship canal is carried a short distance back from the river-bed, in an entirely new cutting, but from here to Manchester the canal follows the river more closely, sometimes using the old channel, and then cutting across the bends. We can readily understand the difficulties encountered in this part of the work, as a temporary channel had to be made to divert the stream before the old bed could be worked at and lowered; and in winter or flood times especially this was very troublesome and costly work.

One flood, in 1892, washed into the newly-made channels nearly 1,000,000 cubic yards of earth, which, of course, had to be taken out again.

At Partington, very large coal docks and chutes have been erected, so that the largest steamers can coal here in a very short time.

A new barge canal has been built, or rather extended from the great Wigan coal-fields, which are only about ten miles north of the canal, so that vessels can obtain coal at a minimum cost. The railroads are building branch lines to connect with the dock constructed in connection with this work.

At Partington and at Irlam, which are about three miles apart, the Cheshire Lines railway crosses the canal, one crossing being for its Liverpool and London line, and the other for its Liverpool and Manchester line. Both are on a heavy skew, and have long spans with the usual approaches.

At Irlam, we come to the junction of the Mersey and Irwell, and from this point the canal follows the Irwell to Manchester in a north-easterly direction, the Mersey turning to the southeast.

At Irlam we also find the next pair of locks, similar to those at Latchford, with five floodgates.

The next important piece of engineering that meets our view is the aqueduct carrying the Bridgewater canal over the ship canal at Barton. This has replaced the famous brick arched aqueduct, built in the last century by the great engineer, Brindley, to carry the Bridgewater canal over the river Irwell. When Brindley proposed his aqueduct, Smeaton was consulted by the Duke of Bridgewater. Smeaton scouted the idea as preposterous, and said he had often heard of castles in the air, but had never before seen any seriously proposed. The aqueduct was built, however, and when taken down on the completion of the new aqueduct, was as sound as the day it was built.

If Mr. Smeaton thought the old aqueduct a castle in the air, what would he have thought of the present structure? The level of the barge canal is about 30 feet above that of the ship canal. To raise it to a clear height of 75 feet, would have necessitated several locks on either side, and Mr. Williams hit upon the happy idea of a draw. The barge canal is now carried in a steel caisson, or trough, which forms a heavy through draw-span, swinging on a central pier, and having a clear opening of 90 feet on each side. Before the draw is opened, this caisson is closed at each end by an automatic gate, as are also the adjacent shore ends of the canal.

The power is obtained from two hydraulic engines, which open the draw in less than a minute.

The weight of the empty draw is over 1400 tons. The construction of this aqueduct was one of the most difficult problems of the entire work, and required extraordinary engineering and mechanical skill. At Barton we reach the next pair of locks, similar to those at Latchford, and provided with floodgates.

The Mode Wheel locks finally lift the ship canal to the level of the Manchester and Salford docks.

The Salford docks have a water-area of 71 acres, and the quays an area of 129 acres. The dock wall has a front length of $3\frac{3}{8}$ miles.

The Manchester docks have a water-area of $33\frac{1}{2}$ acres, a quay-area of 23 acres, and a dock frontage of $1\frac{3}{4}$ miles.

In addition to this, there is a large, dry graving-dock at Salford, owned by a private company.

All the docks and locks are provided with large subways, readily accessible, to convey the hydraulic power from point to point. 1,250,000 cubic yards of concrete were used in the construction of the lock and dock walls. Seventy millions of common brick, or about 180,000 cubic yards were used in the work, and 220,000 cubic yards of cut masonry, in addition to a large quantity of rubble used for paving the canal slopes, and in the interior of dock walls.

Much of the stone for the masonry was taken out of the bed of the canal itself.

The facing of all walls is of cut granite, for fender and coping, and vitrified brick. In fact, the entire construction is of the best and most substantial materials.

The quays are all provided with the most modern hydraulic appliances for loading and unloading vessels, as also with hydraulic capstans for hauling purposes.

Miles of substantial shedding have been erected, and a perfect network of railroad tracks covers the docks, as all the railroads running into Manchester have obtained permission to connect with the docks. About seven barge canals, extending in every direction from Manchester, already connect with the ship canal, so that heavy freight can be transferred from the ship to the barge at a minimum of costs, thus supplying the adjoining manufacturing districts with good and cheap water communication direct from the docks.

The time usually required for a vessel to travel from Eastham to Manchester is from six to seven hours, and as the canal is well supplied with electric lights, traffic can be carried on by night as well as by day. While the ship canal scheme was still in its infancy, the question of the supply and quality of the water for the canal was seriously discussed. At the time when the charter was obtained there had been passed the "Rivers Pollution Act" prohibiting any person or corporation from emptying into a river anything injurious to health, or likely to prove a nuisance to persons lower down the stream. This act, however, was a dead letter, for, at that time, dye works, print works, chemical works, etc., and towns innumerable, were throwing their refuse and sewage into the Irwell, making it red, black and blue by turns, or covering it

with soapsuds, according to circumstances, and rendering the Irwell at that time, perhaps, the filthiest stream in the world. Our Liverpool friends were very solicitous on this account about the health of Manchester, and seemed to fear that at any very low stage of water, or when the sediment was stirred, the Manchester people would all die of the plague. Since the canal was begun the Manchester and Salford Corporations have taken measures to prevent the pollution of the upper stream, with the result that the quality of the river water has very much improved, so much so that the water is now quite fit for canal purposes. The two corporations have also built great intercepting sewers to carry all their own sewage to sewage farms several miles from the city. The percentage of solid matter in the water is, however, still so large that it will always be necessary to keep dredgers at work in the ship canal.

The question of the water-supply required for locking purposes was a more difficult one. The Irwell valley above Manchester has a drainage area of only about 500 square miles, and at times furnished barely enough water for the old Mersey Navigation with its limited traffic. By economizing, however, and by using the water from one lock to help fill its companion, the water required for lockage is reduced to a minimum.

Provision has also been made for pumping water from the lower to the upper reaches, in case of prolonged drought, so that the canal is assured of a plentiful supply of water for all the traffic that can pass through it.

Nine highway bridges cross the canal between Runcorn and Manchester. Two of these are high-level bridges and seven are draw spans, all with 120 feet clear opening. The draw spans are operated by hydraulic power.

The original contract for the construction of the canal was let to Mr. Thomas Walker, who had just completed the Severn tunnel and several other large works. The amount of the original contract was $29,000,000. Mr. Walker divided up the work into six sections, and placed a capable engineer in charge of each.

Mr. Walker contracted to complete the canal in four and a half years, but died in 1892, when the work was about three-fourths completed, when the ship canal company itself took up the work and completed it, opening the canal for traffic on the 1st of January, 1894.

The rate of excavation varied from $\frac{3}{4}$ to $1\frac{1}{4}$ million cubic yards of material per month. As much as 2,400 cubic yards was excavated in ten hours by the German excavator, and 2,000 yards by one of the steam shovels, but these were exceptional days, 700 yards being the average day's work.

The average total cost of excavating earth and loading into cars was nearly four cents per yard.

Mr. Walker had in operation on the work a plant that cost him nearly $5,000,000, consisting of nearly 100 steam shovels, excavators and dredges of various kinds, 194 steam cranes, 182 portable and stationary engines, 209 steam pumps, 173 locomotives, 6,300 dump cars and 223 miles of track. To raise steam for this vast plant, 10,000 tons of coal were consumed monthly.

At one time nearly 16,000 men were employed. It required a master mind to organize and to keep in motion a vast industrial army like this, and it is not surprising that the man who carried this entire burden, at the same time having other extensive works on hand, broke down under the strain.

III. COMMERCIAL RESULTS.

Manchester is the center and great commercial mart of a vast network of towns. The district within a radius of ten miles, excepting a portion on the west side, is one vast city, constituting the greatest cotton manufacturing and industrial center in the world. In this great hive is a population of 4,000,000 souls, while over 7,000,000 live within a radius of twenty miles from Manchester City Hall.

As all the food supply and raw material has to be imported, and the bulk of the manufactured goods exported, one can readily understand that the outgoing and incoming traffic over the canal is conservatively estimated at over three million tons per annum each way. This amount of traffic, at less than one-half the rates charged by the railroads, will give a revenue sufficient to pay all the operating expenses of the canal with interest on the entire capital, and also provide a sinking fund for the repayment of the bonds.

In addition to this, the difference between the railroad rates and the canal rates represents a saving of about $5,000,000 annually, and, on the close margins on which manufacturing is now carried on, this will soon repay the cost of the canal. The dividends payable are limited by the charter, and any excess of profits over this goes towards paying off the bonds and reducing the charges.

The successful consummation of this tremendous enterprise should incite us to similar action. The resources of this country have only begun to be developed, and the only way by which the inland cities can attain their full growth and prosperity is by taking advantage of every favorable circumstance to lessen the cost of production and transportation.

The waterways of the country ought to be taken out of the hands of politicians, and treated on a strictly commercial basis. If a body like

the Corporation of Manchester thinks it worth while to spend $25,000,000 to help carry through the ship canal, it certainly behooves a city like St. Louis, favorably situated as she is, to bestir herself, and by the use and improvement of such a magnificent waterway as she possesses in the Mississippi, make herself the great commercial mart of the Southwest. The people of St. Louis hardly appreciate the importance of the question to them, and this club owes it to them, to influence and educate public opinion on this very vital matter.

THE CONTRIBUTION BOX.

Members of the associated societies, and other persons, are invited to send to the Secretary, for this department of the JOURNAL, such matters of general interest as may come to their notice.

Eminent Domain in Hydraulic Engineering.

Mr. Clemens Herschel, member of the Boston Society, is endeavoring to have incorporated in the Constitution of the State of New York an amendment by which "the necessary use of lands for the construction and operation of works serving to retain, exclude or convey water for agricultural, mining, milling, domestic or sanitary purposes" shall be declared to be "a public use," so that lands may be taken for such purposes by the legislature by right of eminent domain.

Mr. Herschel refers to the existence of such provisions in the codes of the ancient Romans and in those of modern European nations, as well as in the constitutions of some of our own states and in the laws of others, and argues that the absence of such provision in the new constitution of New York and of the remaining states seriously impedes the general development by almost entirely throttling the execution of hydraulic works upon a large scale.

The Western Society's Papers.

The Publication Committee of the Western Society, in its report printed in the Society's Proceedings in this number of the JOURNAL, remarks that up to the date of that report (August 1st) but one of that Society's papers had been published in the JOURNAL this year. It is only just to the Association to observe that until the day before the date of that report but one other paper from the Western Society had reached the editor, and this was Mr. Mead's paper on the Hydrogeology of the Upper Mississippi Valley, which was read in April, 1893, and which reached the editor in March, 1894, or nearly a year later, and appeared in the JOURNAL for July, issued during August.

This is a very long paper, with many extensive tables and elaborate illustrations requiring special care and involving the consumption of much time in their preparation; and the author kindly acquiesced in the editor's suggestion that it be allowed to wait until a number of shorter and simpler papers could be prepared, so that the JOURNAL might the more speedily be brought out of the arrears due to delay in the final transfer of the secretaryship.

Three memoirs and the several Proceedings submitted by the Western Society were published in the issues bearing their respective dates.

THE LIBRARY.

It is proposed to notice briefly in this department of the JOURNAL such engineering publications as may find their way to our shelves.

Publishers are requested, in sending works for review, to state the prices of same.

Compressed Air, The Uses of—. With illustrations. By Addison C. Rand. New York: The Republic Press. 1894. 134 pages, 5 x 7. Handsomely printed and profusely illustrated. $1.00.

This little book, although strongly suggestive of an "axe to grind," forms, nevertheless, a most interesting and useful account of many of the uses to which compressed air is put in various branches of engineering.

Although electricity, and not compressed air, is the means selected for the transmission of the power from the great works at Niagara Falls, yet compressed air played an important part in the driving of the tunnel, and, in view of the striking character of that work, it is not surprising that the author has selected it for the opening chapter of his book.

A photograph of two naked negroes working a percussion-drill in the gold mines of South Africa indicates the extent to which the use of compressed air has penetrated remote corners of the earth. The examples given and illustrated comprise the work on the Chicago drainage canal, the tapping of blast-furnaces, the air-brake, the pneumatic railway signal system, the compressed-air locomotive and street railway car, the unloading of dump-cars, the operation of clocks and engines in Paris, the compressed-air guns of the Vesuvius, aërated fuel, the aëration of water-supplies, the compressed-air paint-brush, the preservation of timber, the manufacture of ice, the pneumatic tire, etc., etc.

City of Newton, Massachusetts. ANNUAL REPORT OF THE CITY ENGINEER FOR THE YEAR 1893. Albert F. Noyes, City Engineer, resigned July 26, 1893; Henry D. Woods, Acting City Engineer from July 26th.

The receipts of the Civil Engineer's Department for the year 1893 were $11,864.97, and the total amount expended $11,860.49, leaving unexpended the modest balance of $4.48, and reminding us of Dickens' definition of happiness and misery as depending upon the side of the ledger upon which the balance of sixpence happened to be found at the end of the year.

Newton, like some larger cities, seems to have been having the Boulevard bee in its bonnet, for early in the year a syndicate of landowners petitioned the county to lay out a line of boulevard from Boston line to Centre Street. The total length of the improvement was to be about four miles, and the cost about $250,000, but the work of construction was postponed owing to an injunction served on the city by one of the parties affected.

During the past year more has been accomplished toward endowing the city with a general park system than ever before, and the amount of sewer extensions during the year far exceeded that of the previous year, and probably reached its maximum.

Archiv für Eisenbahnwesen (Archives of Railroading). Published by the Ministry of Public Works, Berlin. Julius Springer, 1894. Year 1894, No. 4, July-August. 194 pages. Six numbers annually. Price per annum, 12 marks ($3.00).

The present number opens with a paper upon the movement of freight upon German railways during 1893, as compared with that of 1890, 1891 and 1892. The figures are derived from the official statistics, and show a small gain in all respects for 1893. Mr. Sigle, of Düsseldorf, discusses the various items of cost of maintenance of way, and Mr. H. Erlanger the past and present of legislation for the protection of working men (for which the Germans roll up the fine compound or triple-expansion word, "Arbeiterschutzgesetzgebung"), with special reference to the rules for the limitation of the hours of labor for railway employees, passed by the Swiss parliament in 1890. The Russian government projects for an extension of the Russian railways to the northward are briefly handled in an anonymous article. The three principal projects under consideration are: a line to connect the Volga and Dwina rivers, a line from Vologda to Archangel, and one to connect the northern coast of Russia with the railways of Finland. Then follow statistical articles on The Naphtha Industry of Baku in 1893, and on the Railways of Australia. Brief Communications, Legal Intelligence, Book Reviews and a list of new books make up the number.

The Value of Tie Plates in Track Repairs. An Analysis of the Dimensions, Form and Functional Purpose of Tie Plates. Read before the Buffalo Association of Railroad Superintendents, April, 1894. By Benjamin Reece. Issued by the Q. & C. Company. Pamphlet, 63 pages.

From Mr. Reece's preface, in which he relates the story of his conversion, we learn how a pronounced opponent of the tie-plate became not only a meek disciple, but an earnest apostle of that feature of railway construction, and all through the incidental introduction of the Servis tie-plate into some experiments upon track spikes which came under his notice.

The pamphlet is a model of careful preparation and of satisfactory illustration, and Mr. Reece's thorough good English should carry understanding, if not conviction, to the mind of every reader.

Methods of Mine Timbering. By W. H. Storms, Assistant in the Field; Bulletin No. 2 of the California State Mining Bureau. J. J. Crawford, State Mineralogist, San Francisco, June, 1894. Pamphlet, 58 pages, including index.

The author here gives a very thorough and very freely illustrated account of the methods of timbering used in the gold mines of California, together with some of those used in other States where extensive ore bodies are worked. The preparation of the paper has involved the visiting of a large number of mines and a careful study and record of the methods there found in use.

Society Proceedings.

Nova Scotian Institute of Science, Halifax, Nova Scotia. Proceedings and Transactions of ——. Vol. I, Part 3. Second Series. Session of 1892-3.

The Transactions contain Notes on the Miocene Tertiary Rock of the Cypress Hills, Northwest Territory of Canada, by T. C. Weston; The Pictou Coal Field: A Geological Revision, by Henry S. Poole, F. G. S. (an elaborate paper of 116

pages, illustrated by seven lithographic plates); Venus in Daylight to Eye and to Opera Glass, By A. Cameron, who, judging from references to a previous paper on the same general subject, seems to have the Venus bee in his bonnet; The Flora of Newfoundland, Labrador and St. Pierre et Miquelon, by the Rev. A. C. Waghorn; and two papers by A. H. MacKay, LL.D., F.R.S.C., one on an Explosive Gas Generated within the Hot Water Pipes of House Heating Apparatus, and one on Natural History Observations, made at Several Stations in Nova Scotia, during the year 1892.

In his first paper, a very short one, Mr. MacKay describes his experience with a gas, evidently nearly pure hydrogen, given off from a tap at the upper extremity of a steam house-heating system.

LIVERPOOL ENGINEERING SOCIETY. Transactions of the ——. Vol. XV. Twentieth Session. Liverpool, 1894.

This volume of 221 pages and 11 lithographic plates contains the following papers: Some English Waterways, by J. A. Saner; The Adjustment of Surveying Instruments, By Ivan C. Barling; On Water-saving Machinery, by F. M. Evanson; A Tour in South Africa, with Reference to Engineering Work, Past and Present, by G. L. Burton; The Public Supply of Electrical Energy, its Cost and Price, by A. Bromley Holmes; Street Pavements, by James Morgan; The Science and Progress of Gas Combustion, by C. R. Bellamy; Some Methods of Regulating the Pressure in Electric Light Circuits, by Wilfrid S. Boult; and Notes on the Distribution of Water Supplies, by Thomas Duncanson.

FRANKLIN INSTITUTE. The Journal of the ——, August, 1894, contains papers on The Graphics of the Efficiencies of the Steam Engine, by Prof. R. H. Thurston; on A Recently Discovered Series of New Cellulose Derivatives, by Clayton Beadle; on the Heating and Ventilation of Large Buildings (continued), by Alfred R. Wolff, M.E.; on Engineering Practice and Education, by Prof. Gaetano Lanza; on A Theory of the Actual Earth Pressure (highly mathematical), by P. Vedel, C.E., member of the Western Society of Engineers; on an Investigation of a Bitumen from Park County, Montana, by William C. Day and A. P. Bryant; and on a Discovery of Anthracite Coal near Perkiomen Creek, Pennsylvania, by Oscar C. S. Carter.

ILLINOIS SOCIETY OF ENGINEERS AND SURVEYORS. Ninth Annual Report; being the Proceedings of the Society at its Ninth Annual Meeting, held at Champaign, Ill., January 24, 25 and 26, 1894.

This Society rejoices in a list of 85 active and 2 honorary members, and the present report is a pamphlet of 120 pages, made up chiefly of a large number of short papers, many of them accounts of pieces of actual work or of discussions of some special features connected with them. Thus, Mr. Pence recites his experience with creeping rails on pile bridges over Galveston Bay; Mr. Benson describes and illustrates the cribs and retaining walls of the railroad embankment along the Columbia River in the State of Washington; and Mr. Cantine describes a viaduct of twenty-seven plate-girder spans near Granite, Idaho. Nearly five pages (none too much, we dare say) are devoted to a paper by Mr. Alvord on Methods of Driving Stakes, and Professor Talbot discusses at some length the various formulas for determining the rate at which storm water may be expected to reach a sewer, illustrating his paper with two diagrams, one representing the classic Burkli-Ziegler formula, and the other a comparison between that and other formulas, including two submitted by Prof. Talbot and by Mr. McMath, respectively.

The Committee on Weights and Measures, in its report, very pointedly likens the dismay of the American upon encountering "£. s. d." in England, with that of the Frenchman or German, who finds us still adhering to our monstrous and innumerable complications of feet and inches, pounds and ounces (of various persuasions), bushels and pecks and gallons, etc., etc.

The Legislative and Judiciary Committee submits a draft of a bill proposed by it to provide for the examination and licensing of land surveyors.

Mr. Daniel W. Mead, of the Western Society of Engineers, whose elaborate paper on the Hydro-geology of the Upper Mississippi Valley formed the major part of the last number of the JOURNAL, is President of the Illinois Society; and Mr. Jacob A. Harman, to whom we are indebted for a copy of the report, is Executive Secretary and Treasurer.

IOWA SOCIETY OF CIVIL ENGINEERS AND SURVEYORS. Proceedings of the Sixth Annual Convention, held at Cedar Rapids, Iowa, January 17–18, 1894.

This report, like that of its sister society in Illinois, is made up principally of short papers. These include: Sanitary Problems, by M. Tschirgi, Jr.; Paving and Sewering for Smaller Cities, by B. Schreiner; Coal Mining in Iowa, by G. A. Davis; Improvement of Highways, by C. R. Allen; and Cemetery Work, by the Secretary, Mr. Seth Dean, whose portrait embellishes the number, as does also that of the President, Mr. William Steyh.

The Committee on Legislation submits a copy of an Act to promote the improvement of highways, which was proposed in the State Senate, but lost; an Act requiring that plats covering additions to incorporated towns or cities, or lands lying within them, shall be submitted to the town or city council for approval, and an Act providing for the breaking and loading of stone by convict labor. The last two, like the first, are among the "things hoped for."

The society numbers 43 active and 6 honorary members.

The report is a pamplet of 45 pages and is notable for its typographical excellence.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XIII. SEPTEMBER, 1894. NO. 9.

THE WEST-CHICAGO STREET RAILROAD TUNNEL, UNDER THE CHICAGO RIVER, NEAR VAN BUREN STREET.

BY CHARLES V. WESTON, ENGINEER-IN-CHARGE, MEMBER OF THE WESTERN SOCIETY OF ENGINEERS.

[Read May 2, 1894.]

INTRODUCTORY.

WITH the adoption of cable railways, to connect the north and west sides of the city of Chicago with the business center on the south side of the Chicago River, came the problem of carrying the cables across the stream.

An element of uncertainty entered into the operation of the cables across the swinging bridges which span the river, and the ever-present "bridge nuisance" thus presented an effectual bar to the complete success of any system of rapid transit which proposed the use of these bridges. Fortunately the city of Chicago owned two tunnels which passed under the river, one situated in Washington Street, the other in La Salle Street. Both of these tunnels had been practically abandoned by the public, and the cable railway companies were enabled to make arrangements with the city for the exclusive use of the tunnels in the operation of their cables.

This arrangement at once overcame the principal obstacles to the successful operation of cable railways across the river, and removed the chief cause of interruption to travel between those sections of the city

which are separated by the stream. The first west-side lines of street railway operated by the cable system were those on Madison Street and on Milwaukee Avenue.

The traffic on each of these lines is very heavy, and is carried under the river through the Washington Street tunnel and around the loop on the south side by a cable taking the traffic from both roads.

In 1889 it was decided to substitute cables for horses on the Blue Island Avenue and South Halsted Street lines, and it then became necessary to make provision for sending the traffic of these lines to the south side of the city, under the river, instead of over it as before. It could not be carried through the Washington Street tunnel, for the loop cable passing through that tunnel was already loaded to its utmost capacity with the traffic from the Madison Street and Milwaukee Avenue lines.

The railway company therefore determined to build a new tunnel for the accommodation of traffic from the lines of street railway lying south of Madison Street, and Mr. Samuel G. Artingstall, a member of this society, was engaged to prepare plans for the structure. The plans adopted correspond very closely with the figures here shown; but a few changes in details were made from time to time as the work progressed.

ALINEMENT AND GRADES.

The line of the tunnel is located upon private property situated between Van Buren and Jackson Streets, and passes under the Chicago River, under several large buildings, and under the yards and tracks of the Pennsylvania Railroad Company near the southern entrance of the Union Passenger Station at Canal Street.

The tunnel and its approaches, extending from the east line of Clinton Street to the west line of Franklin Street (see plan and profile, Figs. 1 and 2, Plate I), comprise a length of 1513.9 feet; consisting of the west approach 316.5 feet, the tunnel proper, 920 feet, and the east approach 277.4 feet.

The alinement is practically straight, and the gradients range from 1.81 to 10 per cent.

RIVER SECTION.

The river section of the tunnel was constructed within coffer-dams one-half at a time; the navigation of the stream making it necessary to keep one channel unobstructed at all times. The land sections were constructed entirely in open trench. The soil cut through was chiefly a semi-fluid clay, very treacherous and difficult to control. This fact, together with the surcharge of lofty buildings, and the vibration due to the railway traffic overhead, rendered imperative the use of a very heavy type of timbering.

On the 6th of February, 1890, active construction was begun on the coffer-dam in the west channel of the river. A sectional view of this coffer-dam is shown in Fig. 3, Plate II. The depth of the water in the river at the site of the dam was 20 feet. The total width of the dam, out to out of the walls, was 90 feet; and the clear width inside 58 feet; leaving 16 feet for the thickness of the walls around the enclosure, from out to out of the piles. The puddle wall was 12 feet thick.

The main piles *P P* in the dam were of oak, 45 feet in length, and spaced in the rows 3 feet from center to center. They were so driven as to leave the head of the pile about 4 feet above the surface of the water or 5 feet above the city datum; making about 21 feet of pile actually driven into the ground.

After being driven, the rows of piles were brought approximately into line by bolting on the outside of each row near the top, a 12-inch square oak wale *W*. Close sheet piling *p p* of pine timber 6 inches x 12 inches, and 34 feet long, was driven on the inside of the rows of oak piling, and the whole was firmly tied together with struts and iron rods spaced about six feet apart.

The space between the rows of sheet piling was then filled in with muck and stiff clay dug up from the bottom of the river.

Oak wales, *w w*, 12 inches square and running the full length on each side, and across the end of the dam, were firmly drift-bolted to the oak piles at distances of 5 feet apart vertically center to center; the joints in the wales were butted, and a splice firmly bolted on the face of the timber over each joint. The cross-braces, *B B*, were 56 feet long, and were composed each of four sticks of pine timber 12 inches square; two sticks, each 28 feet long, were butted together for the center of the brace, and over the joint were placed top and bottom splice-sticks 12 inches square and 20 feet long. These four sticks were securely fastened together with iron bands, and the strut thus formed was cut to the proper length to fit snugly between the oak wales. In all cases care was taken to have the braces placed perfectly horizontally in the work.

The braces in the first tier were placed at the water line. The braces in each tier were spaced 9 feet center to center horizontally, and 5 feet vertically, to correspond with the spacing of the wales. To give them lateral stability, 12 inches x 12 inches struts, *S S*, 8 feet long, were inserted between them.

The horizontal spacing was decided upon prior to the construction of the dam. The safe vertical spacing was determined by actual experiment as the water was pumped out. The first attempt to clear the dam of water was unsuccessful. When the water had been lowered about four feet the wales developed weakness to such an extent that it

became necessary to again flood the dam and strengthen the walls by driving a close row of oak piles (Fig. 4) in front of the oak wale which had already been placed, omitting a pile wherever a strut occurred in the first tier. An example of the failure of the oak piles spaced three feet centers is shown in connection with the section through the crib-dam (Fig. 4).

At the point represented in Fig. 4 the ground below the bed of the river was especially soft, and readily yielded to the superincumbent weight of the puddle wall. Every pile of the inside row across the end, was broken at from six to eight feet below the bed of the river, or near the center of the stick. The average diameter of the piles where broken was $12\frac{1}{2}$ inches.

The braces supporting the end of the dam were 12 inches square, and eight of them were used in each tier. They were spaced 7 feet center to center horizontally, and were carried to the side wales at an angle of about 40 degrees with the longitudinal axis of the dam. The vertical spacing of the end braces was at first 5 feet centers, or the same as that of the cross-bracing; but before the excavation had reached a depth of five feet below the bed of the river, it became necessary to put in intermediate tiers of braces, beginning with the space between the second and third tiers of the original bracing. Until this was done the movement in the broken piles at the end continued with sufficient force to produce deflections of one inch at the center of the 6 feet spans of 12 inch square oak wales, and in one instance the wale was completely broken.

Assuming the coefficient of elasticity of the timber at 1,500,000 pounds per square inch, and the maximum deflection at the center of the 6-foot span to have been one inch, then for the beam fixed at both ends and loaded at the center (which was the case here), the total load would be 70,000 pounds; and, since the area supported by each section of waling was 35 square feet, it follows that the lateral pressure of the earth at that point was 2,000 pounds per square foot.

After the water had been pumped out of the dam, a pile-driver was mounted on the top tier of cross-braces, and two rows of piles, *R R*, 40 feet apart, were driven to form the sides of the excavation to be made within the coffer-dam. The piles were spaced 3 feet centers, and the space between the piles was securely planked up as the excavation progressed. The cross-braces in the excavation were single sticks 12 inches square, spaced 9 feet centers horizontally and 5 feet vertically. This type of timbering was used throughout in the land and river sections, with some modifications to suit special conditions.

After the completion of the masonry in the west half of the river, a crib-dam, Fig. 4, was built across the arch near the toothing of the brick

work, and water-tight connections were made with the sides of the coffer-dam.

The crib-dam was of course built in the dry enclosure. We first laid down a timber, scribed to the concrete backing over the crown and edges of the arch, and carried to the sides, and then we buried that timber in concrete. First, however, we put up our uprights, to which the 6 inches by 12 inches sheathing was fastened, and then, back of the scribed timber at the bottom which was buried in concrete, we put a bed of clay. Then again, after the old structure had been removed, we put more clay on the outside around the corners. We had no difficulty whatever with this little dam, except in one corner, where a piece of the sheathing in the old structure had been withdrawn. It appeared that an iron rod had been passed through where we wanted to put in a new piece of sheathing, and this interfered with our placing it. After we had pumped out the eastern dam, water worked through where the piece of old sheathing had been withdrawn. It was not a very bad leak. We tried to stop it by driving down square sticks in the soft clay, and we did succeed in shutting the water off two or three times, but as often it started to leak again. Finally we stopped the leak by forcing into the opening cement bags partially filled with cement. It took us perhaps a week to accomplish that little thing, but we then had no further trouble with the dam.

After the completion of the crib dam the remainder of the coffer-dam between the crib dam and the west dock was cleared away, and the west channel opened to navigation.

The coffer-dam was then built across the east channel of the stream. This dam was in all respects similar to the one built in the west channel, except that the piles used were of large *Norway Pine*, driven as close as possible, and on the center line of the tunnel a row of piling was driven for the support of the cross-braces. This arrangement made practicable the use of single short sticks of timber for the cross-braces, instead of the unwieldly built-up struts used in the coffer-dam in the west channel. No trouble was experienced in the construction and maintenance of the second dam.

STRUCTURE UNDER RAILROAD CROSSING.

Among the most difficult and dangerous features of this work was the supporting and maintenance of the tracks and interlocking system in the yard of the Pennsylvania Railroad during the excavation of the trench. See Figs. 5, 6 and 7, Plate II. Before any attempt at excavation under the railroad track was made, piles were driven to support the sides of the trench and to carry the superstructure on which the tracks were to rest. The trench under the yard was 42 feet in clear width, and

wherever it was possible to drive a pile, in or between the tracks and along the side lines of the trench, a pile was driven. The spacing of the piles in these rows varied from 2½ to 4 feet, center to center. Two additional rows of piles were driven 15 feet apart between centers, dividing the width of the trench into three equal spaces. These piles were so located as to give the best possible support to the tracks, the spacing being generally 9 feet centers, and were tied together in pairs with 12 inches square pine caps x x. The longitudinal caps c c to receive the track stringers s s were placed above the cross-caps x x, and consisted each of two 12-inch square timbers placed one above the other. The track stringers s s were 7 inches by 14 inches pine timbers, 55 feet long, extending entirely across the trench. Track ties were of sawed oak, and the entire space in the yard over the excavation was planked over with 3-inch oak planks. The structure was placed under one track at a time, the work being usually done during the night when the Railroad Company could give the contractors hours for working which would not interfere with the movement of trains.

The most troublesome feature of this work under the railroad yards was the swelling of the soft clay encountered at a depth of 20 feet below the surface. Here the clay was very wet, and of about the consistency of putty. When once stripped of the material above, it was quickly forced up by the weight of the material which was held back by the timbering at the sides. As the whole surface of the bottom of the excavation gradually rose, the earth at the sides settled and carried with it the timbering, the piles being literally forced into the ground. As the sides settled, the superstructure under the tracks was kept to surface by shimming.

An attempt was made to arrest the movement in the timbering by introducing additional cross bracing, which was placed in the structure at an inclination, so that, as settlement took place, the braces should be tightened. This method completely failed to accomplish the desired result, and it was only by loading the bottom of the excavation with a large quantity of rubble stone that the forces were brought into equilibrium. The excavation was then carried forward in very short sections, and the concrete for the invert arch, and the footing for the skew-back, were placed in each section when the excavation reached grade. It is an interesting fact, that throughout this whole work, all movement in timbering, and all settlement in the ground back of it, ended as soon as the concrete invert arch was in place.

ARRANGEMENTS FOR THE SUPPORT OF BUILDINGS.

The original plans required, that before work in the tunnel was commenced, all buildings over the site of the tunnel should be under-

pinned, and supported on foundations extending downward to a level below the bottom of the tunnel excavation. The foundations to support the side walls of the seven-story building (Nos. 234 and 236 Market Street) fronting on the river and on the west side of Market Street, were to be of cast-iron cylinders. Those under the north walls were to have been 6 feet, and those under the south wall 7 feet, in diameter, and the thickness of the metal 1¼ inches. It was intended to bring the cylinders to the site of the work in the sections six to eight feet in length, each section (except the lower end of the bottom section) to have top and bottom internal flanges, 4½ inches wide. When one section had been sunk, another section would be bolted to it with 1⅛-inch bolts, about 5 inches apart. The joints between the flanges were to be caulked and made water-tight. The specifications required that these cylinders should be sunk in the center of the walls, perfectly plumb, and be filled with concrete thoroughly rammed in place, and capped on top with a granite block 2 feet thick, 4 feet wide and 6 or 7 feet long. Between these cylinders should be turned brick arches, backed and underpinned to the existing walls with brick masonry of clinker pressed bricks laid in Utica cement mortar.

After the cylinders were sunk to place and the walls of the building made secure, the floors were to be supported by temporary trusses, which were to remain until the tunnel below had been completed. After this was done the cast-iron columns supporting the floors were to be replaced on foundations built of concrete and timber, in the same manner as they are now supported.

During the progress of the work, both the Market Street front and the river front of the building were to be supported by steel girders resting on piers of pressed-brick laid up in Portland cement mortar. The foundations of the piers were to be of concrete, and were to extend down below the bottom of the tunnel foundation. The pier foundations at the river front were to have been 10 feet x 20 at the bottom.

The foundations for the side walls of the building, Nos. 233 and 235, on the east side of Market Street, were to be of concrete, to extend down below the bottom of the tunnel, and to receive the side walls of the building, which would be underpinned with common brick masonry. It was intended to put the foundations down and underpin the side walls in short sections, in the meantime supporting the front and rear walls on steel girders.

The contractors were also required to be responsible for the safety and security of all buildings adjoining the tunnel, during the prosecution and after the completion of the work.

The contract, however, contained a stipulation which gave the contractors the right to take down the buildings and restore them again

after the completion of the tunnel, instead of underpinning and supporting them as above described. This, after mature consideration, they decided to do, believing it to be the cheaper and less dangerous method.

Having determined to remove the buildings over the site of the tunnel, for the greater security of the adjacent structures during the excavation of the tunnel trench, it was decided to change the character of the foundations on which the buildings over the tunnel and on both sides of Market Street were to rest when restored. In each of these foundations the piles are 45 to 50 feet in length, spaced 2 feet 6 inches center to center and driven in four rows running the full length of the building, the inside row forming a support for the sheathing for the sides of the tunnel excavation. After the piles were driven, the heads were cut off at 1 foot 6 inches below city datum and capped with 12-inch square oak caps. The space between the caps, and to a depth of one foot below the tops of the piles, was filled in with concrete, the whole being covered with an oak floor 6 inches thick, on which rest the dimension stones forming the footing courses under the walls.

In the seven-story building Nos. 234–236 Market Street the interior columns carrying the floor system are supported by large concrete footings which rest on the arch of the tunnel; and the front and rear walls are similarly supported on concrete footings, instead of the steel girders originally proposed.

The tunnel proper extends less than 50 feet under the building Nos. 233-235 Market Street, the remaining 100 feet under that building being occupied by the eastern approach. The approach walls under this building carry a system of built steel girders, which span the approach and support the interior columns and floor system of the building above. Between the girders are I-beams, carrying brick arches backed up with concrete, forming a fire-proof floor over the approach. This fire-proof floor is sufficiently strong to withstand the shock of falling debris in the event of the destruction of the building by fire. The front and rear walls of this building are supported on steel girders, as originally intended.

On the west side of Market Street, not only was the building Nos. 234–236 immediately over the tunnel taken down and restored, but it was also necessary to remove one-half of each of the two buildings adjoining the tunnel property. The remaining portions of these buildings were supported on screws, and used for storing all the building materials (excepting the brick) which had been removed from the buildings taken down. As the excavation progressed, the moisture was drawn from the ground under the foundations of the party-wall of an eight-story building situated 50 feet north of the trench and entirely occupied with manu-

facturing and merchandise, and it became necessary to support that wall on screws in order to keep it to its proper level. This was accomplished without serious interference with the business of the occupants, and when the wall was underpinned after the completion of the tunnel it was found that the settlement of the foundations under the screws varied from 6 to 13 inches. All structures taken down were restored, and made good in all respects, and the alterations necessary to adapt them to the changed conditions, were made.

THE APPROACHES.

The masonry in the side walls of open approaches is faced with Bedford stone, laid in regular horizontal courses 18 inches in thickness. The stone is rock-faced, and no projection of the face beyond the line of the work exceeds 1½ inches. The stone is laid header-and-stretcher, well bonded together and to the backing, not less than one-third of the face of the wall being composed of through stones. The backing of these walls is of Joliet limestone, laid in courses of the same height with those of the facing. All of the walls are laid up in Portland cement mortar throughout. The coping is 4 feet wide by 2 feet thick, and is planed on all faces. The foundations under the walls, and the invert between them, are of Portland cement concrete. The sections of the walls vary according to the height; the thickness of the wall at the center being generally not less than one-third of the total height.

THE TUNNEL SECTION.

The tunnel, Figs. 8, 9, 10 and 11, Plate III, is a three-center arch with a clear span of 30 feet and a clear height of 15 feet 9 inches.

The minimum thickness of the ordinary tunnel section, including the concrete backing, is 4 feet. See Fig. 8, Plate III. The minimum thickness in the section under the railway tracks is at the crown, where it is 4 feet 6 inches. At the sides the thickness is 5 feet 6 inches. The total width of the ordinary section, out to out of walls, is therefore 38 feet, while that of the special section under the railway track is 41 feet. From an economical point of view, the clear width is excessive, and for all practical purposes it might have been reduced 4 feet; but the adapted width was given in order to avoid accidents to passengers. The clear width between the walls of the La Salle Street and Washington Street tunnels is only 19½ feet, and the maximum width of the cars operated through these tunnels, out to out of steps, is 9 feet 1 inch. Passing trains therefore occupy 18 feet 2 inches of the 19½ feet clear width, leaving a very narrow margin between the steps of passing cars and between the cars and the walls of the tunnel. It is impossible to prevent passengers from taking the risk of riding through the tunnel while standing on

the steps of the cars, and several fatal accidents have occured to passengers who have been thrown from the steps of the cars by coming into contact with the side walls, while riding through the tunnel.

The arch is of brick masonry, seven rings or 32 inches in thickness. The bricks used throughout the work are hand-made, hardburned sewer bricks of standard dimensions, viz.: 8 by 4 by 2¼ inches. The bricks are laid longitudinally with the tunnel, with the edges toward the center and with toothing joints. Much care was given to so place the laggings on the ribs of the center that the edges were parallel with the grade of the tunnel, and the bricks in the first ring were laid true to the face and edges of the laggings. The result in the finished arch was very gratifying. The courses of the brickwork are remarkably true to line, and they everywhere conform very closely to the inclination of the grade. The joints between the courses are not more than ½ inch in thickness, and those between the shells or rings not less than 1 inch in thickness.

In the two outer rings of masonry, under the river, and for 100 feet on each side of the river, a total length of 420 feet, and in the outer ring of masonry in all other parts of the tunnel, the bricks were laid in, and grouted with asphalt mortar, composed of Trinidad asphalt and gypsum, mixed generally in the proportion of one part of asphalt to three parts of gypsum. This mortar was mixed on the ground and furnished hot, ready for use in small quantities as required. Asphalt mortar which had once set or had become cold was not allowed to be remelted for use in the work. The object in using the asphalt mortar, was to provide a protection against the leakage of water, or dampness in the tunnel; the idea being to produce a mortar that would adhere firmly to the bricks, and to be elastic enough to conform to any settlement in the masonry without leaving open joints; but considerable difficulty was experienced in producing with these materials a mortar which would not in very hot weather become so soft as to fail to hold the bricks in position, or, in very cold weather, so brittle as to leave open joints in case of settlement in the masonry. After various experiments, the most satisfactory results were obtained by mixing with the asphalt mastic, from 10 to 15 per cent. of coal-tar pitch. But it may be said that none of the mixtures obtained gave an ideal result. Much depends upon the manipulation of the materials in preparing them for use. If the mastic is over-heated, or if the gypsum is not properly prepared and thoroughly mixed with the asphalt, the result will be unsatisfactory.

The temperature of the mortar varied. The gypsum was brought to sufficient heat to make it perfectly dry. It was used as an absorbent to hold the oil and to prevent it from leaving the asphalt and going into the bricks. The chief difficulty in preparing this asphaltic mortar was in keeping it evenly heated. It was necessary to keep it hot, and some-

times, when we were delayed in getting ready for its use, it boiled too long. In that case a certain amount of oil evaporated and the asphalt became too brittle. This could not readily be remedied by adding more oil. The difficulty was to find out when the mortar had been overheated. If we had always known the condition of the mortar when it was taken from the heating pans, we could no doubt have regulated the amount of oil, but the difficulty was in determining when it had been cooked enough, or when too much. The ideal mortar would be made with gypsum perfectly dry and the asphalt mastic brought to the boiling point, and the two thoroughly and uniformly mixed in the proper proportions.

The asphalt mortar was made entirely by hand. It was impossible to mix it with a machine, for we used it in small quantities and tried to so regulate the supply as to meet the varying demand.

The outer ring of brickwork throughout was covered with a coating of the asphalt mortar about 1 inch in thickness. All brick masonry in the tunnel (except those portions already referred to as being laid in asphalt mortar) was laid in Utica cement mortar, which was made by thoroughly incorporating one part of cement to two parts of clean lake-shore sand, and mixing them with water to the proper consistency.

The invert arch, the backing and filling over the haunches, and the footings under the skew-back are of Portland cement concrete well rammed in place. All spaces between the masonry and the sides of the excavation, and all irregularities, were filled in solid with concrete. Each day's work of bricklaying was backed up with concrete during the night. The sheeting was removed and the concrete well rammed into the clay, which soon effectually sealed the concrete against leakage of water.

The length of the section which could be concreted at one time depended chiefly upon the weather. In dry weather the water drained from the sides of the excavation; but during or after a wet season the stability of the soil was very much decreased. The earth was then very unstable and the bottom swelled very readily. Sometimes we put in sections not more than 10 feet long, again some that were 50 feet long.

All concrete used in this construction was made by thoroughly mixing Portland cement mortar with clean, sound, broken limestone, not exceeding three inches in any direction. The mortar was composed, by measure, of one part of Portland cement and three parts of clean, sharp sand. These were uniformly mixed in a dry state; and to this mixture were added six parts of the broken stone, with only sufficient water, added gradually, to produce a mixture of the proper consistency. The Portland cement used in this work was the "Empire Brand," manufactured at Warners, N. Y. It was subjected to the following

test: Not less than 90 per cent. must be capable of passing through a wire sieve having 2,500 meshes to the square inch; a briquette made with the minimum quantity of water must take not less than three hours or more than six hours in setting; the increase in temperature during setting must not exceed 5° Fahrenheit; briquettes left in air or placed in water must not show any deviation in form; briquettes of neat cement, gaged with a minimum quantity of water and kept immersed in water during the last sixty out of seventy-two hours, must withstand a tensile strain of 175 pounds per square inch at the end of seventy-two hours after gaging, and those tested at the end of seven days after gaging must show an increase of at least 50 per cent. over the strength of those at three days, but should carry a minimum of 350 pounds per square inch, and at the expiration of twenty-eight days should increase in strength at least 25 per cent. over those tested at the end of seven days. Any cement which deviated more than 10 per cent. from these requirements was not allowed to enter into the work.

I have, however, always considered it better policy to use cements which run uniform in quality and which come within reasonable limits of the established standard, rather than to arbitrarily condemn such cement for a slight variation from the standard. Uniformity in quality is one of the principal requisites for the cement to be used in a large construction of this character.

The east portal is shown in Figs. 12 and 13, Plate III, and the west dock wall in Figs. 14 and 15, Plate II.

CENTERING.

The centering used in this arch, shown in Figs. 3 and 7, Plate II was very much heavier than would have been necessary to support merely the weight of the masonry. The ribs of the center were spaced 4 feet 6 inches, center to center. These ribs were 14 inches deep and 8 inches in thickness, being made from four pieces of 2-inch plank firmly bolted together, with joints well broken in order to give the ribs the greatest possible strength. Each rib contained ten radial struts of 6 inches by 8 inches pine timber, and the struts were supported at the center of a 12 inches by 12 inches cross-brace snugly fitted between the striking plates and supported at the center by posts extending down to the concrete invert arch.

The lagging was of 3 inches by 4 inches boards, dressed down to $2\frac{3}{4}$ inches. These were placed close together on the ribs of the center. Very few nails were used, except of course near the bottom on each side. As we brought up the courses of brick laid in asphaltic mortar it was very difficult to keep the lower courses erect, the mortar acting as a fluid and drawing off from the inside rings of masonry. We kept them

in position by putting struts against them until the mortar had set sufficiently to hold them in place. We left these temporary braces in until the concrete backing was brought up to hold the bricks in position.

The necessity for making these centers so extremely heavy was, that as the brick masonry was carried up to the height of the various tiers of cross-braces which supported the sides of the excavation, it became necessary to release the cross-braces, and the centers took the stress transmitted from the sides when the cross-beams were loosened. As already stated, the cross-beams of the coffer-dam were spaced 9 feet center to center horizontally, and deflections of 2 inches have often occurred in the 18-foot span of oak waling when the braces were cut loose. If the centers had not been sufficiently strong to support this lateral pressure in addition to that of the arch, the green masonry of the latter would have been permanently injured.

PROGRESS OF WORK.

On account of protracted litigation between the Tunnel Company and the various property owners along the line of the tunnel, it was impossible to prosecute the work continuously from any given point, but the entire tunnel and the approaches thereto were constructed in several sections often remote from each other. The section in the west half of the river and one hundred feet inland was first constructed; then the east approach from the west building line of Franklin Street westwardly one hundred and forty feet was completed. Then followed the simultaneous construction of the section under the Pennsylvania Railroad yards, and that between the east dock line and the center of Market Street. The completion of these two sections was followed by the construction of the river section in the east half of the river, which connected the sections previously constructed, making the completed work continuous from the center of Market Street, east of the river, to the east curb wall in Canal Street west of the river. Then followed the construction of the portion from the center of Market Street eastward, to join that portion of the open approach which had been built westward from the west line of Franklin Street. The last section, which included the arch under Canal Street, and the entire west approach and portal, was then built, completing the entire work. The time covered by construction and delays was a little more than four years, or two years more than the time originally contemplated.

Although the tunnel and approaches were built in this fragmentary manner, the joinings were perfect in alinement and grade, and no unequal settlement or deviation from the true section can be detected in the several joinings. This result I consider to be in a large measure due to the great strength of the centers, and to the fact that we were able to

leave them under the completed arch a sufficient time for the mortar to become thoroughly set before striking. The last section of the arch built was the only case where the centering was removed soon after keying. The centers in this section were struck within twenty days after the arch was keyed; but, although I have closely examined this section of the arch several times since the removal of the center, I have been unable to detect any settlement at the crown or any deviation from the true arch as turned. As soon as practicable after any portion of the masonry of the tunnel was built, the trench over it was filled up in uniform layers, and the filling was rammed thoroughly in place to a height sufficient to bring the surface to its original level.

DRAINAGE.

The tunnel (see Fig. 2, Plate I, and Figs. 8, 9 and 11, Plate III) is drained by means of a 12-inch pipe laid on the invert along the center line of the tunnel and its approaches, with brick manholes for cleaning, about 200 feet apart. There are also (in the land sections only, Figs. 8 and 9) vertical lines of drain pipe back of the side walls. These vertical drains are 4 inches in diameter and about 50 feet apart. They are connected with the main drain in the tunnel by means of 4-inch cast-iron pipes. The cable tubes of the railways are connected with the main drain by short pipes laid at intervals of 32 feet (Fig. 9). All manholes and wheel pits in the cable tracks are also connected with this main drain, which discharges into a sump (*S*, Fig. 2) at the lowest part of the tunnel, near the center of the river. The sump is connected by a 20-inch drain pipe with pump-well (*W*, Fig. 2) at the north side of the tunnel, just east of the dock-line, where a brick shaft 6 feet in diameter, reaching to the surface of the ground and occupying a recess formed in the side wall of the tunnel, contains a drainage pump which raises the water and discharges it into the river above.

COST, ETC.

This tunnel cost $800,000 for actual construction, and $1,000,000 for property along the line and for legal expenses.

The contract for the construction was awarded to the Fitzsimons and Connell Company, and sub-let by them to Messrs. Joseph Downey & Co.; the latter firm being composed of Mr. Joseph Downey and General Charles Fitzsimons, of the Fitzsimons & Connell Company. These gentlemen had a great many difficulties to overcome, and met them with great courage and fortitude.

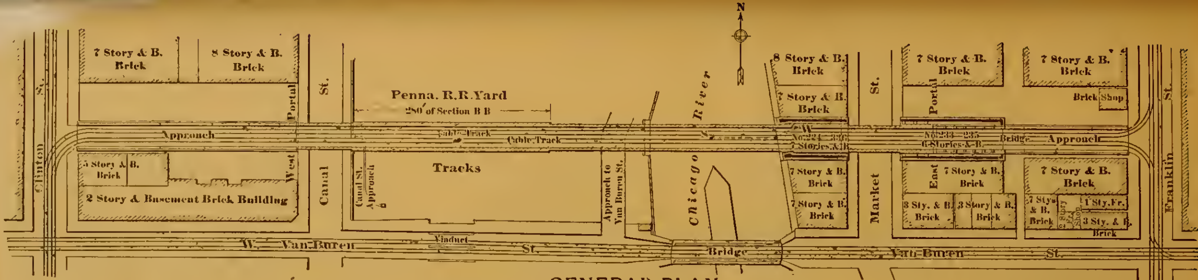
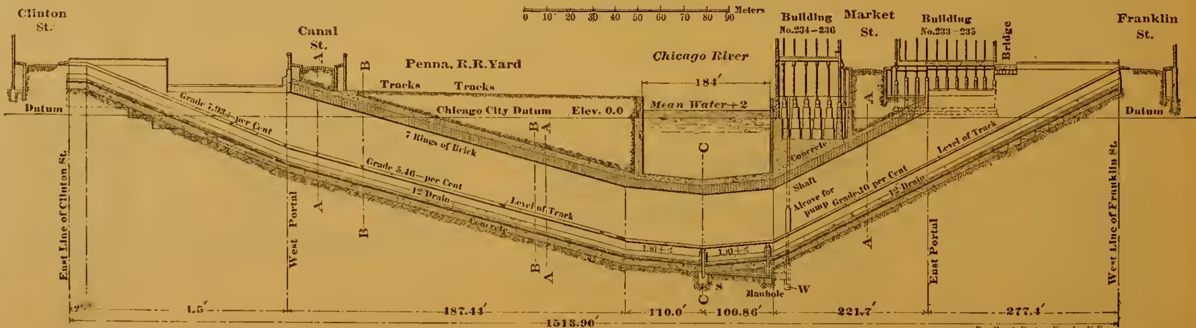


Fig. 1

GENERAL PLAN



PROFILE.

Horizontal Scale, 1 inch = 200 feet; or 1 = 2400.
Vertical Scale, 1 inch = 40 feet; or 1 = 480.

Fig. 2

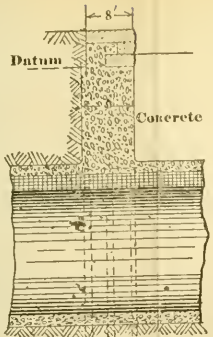


Fig. 14
SECTION

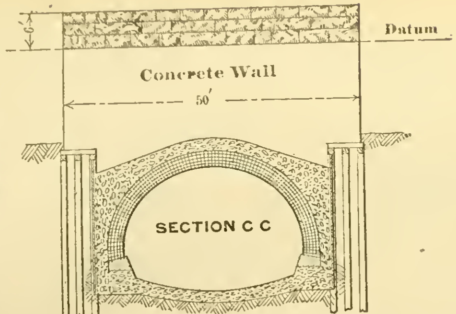


Fig. 15
FRONT ELEVATION

West Dock Wall

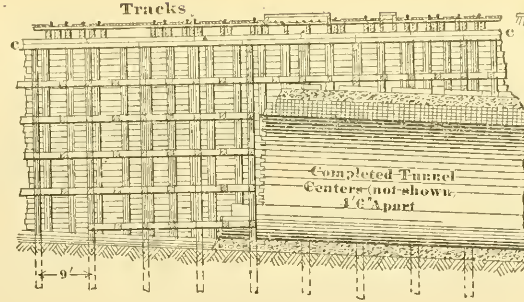
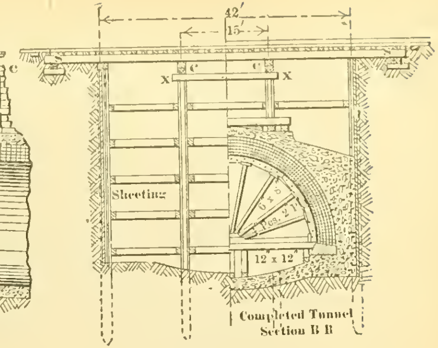
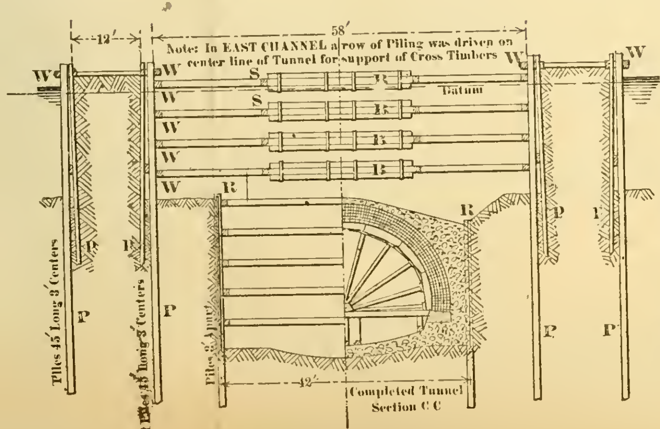


Fig. 6
LONGITUDINAL SECTION



SECTION N O
Fig. 7

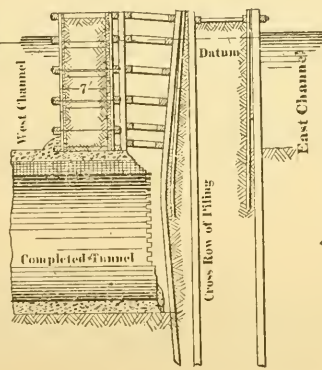
Timbering under Railroad Tracks



SECTION OF COFFER DAM
WEST CHANNEL
Fig. 3

SECTION OF
CRIB DAM

SECTION OF END
OF COFFER DAM



CRIB DAM
Fig. 4

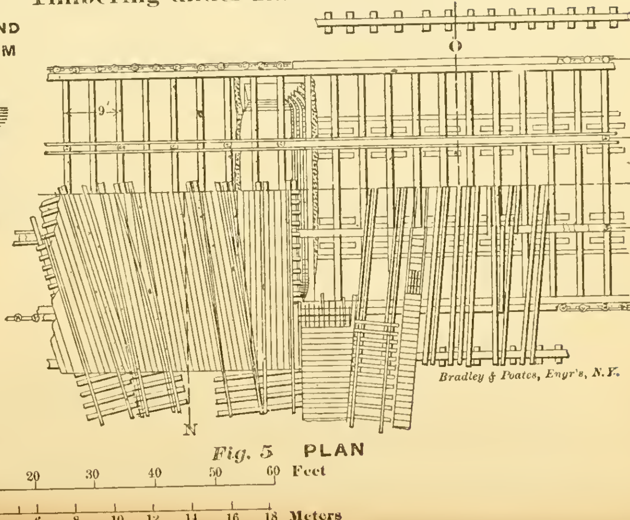
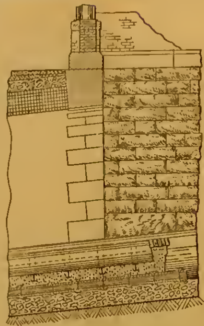


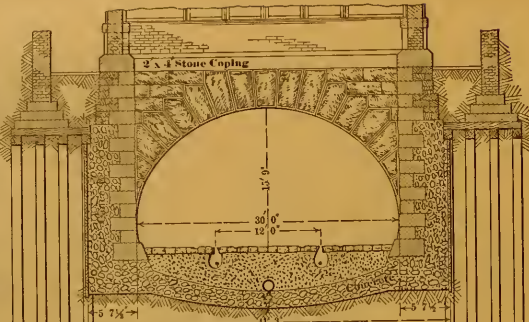
Fig. 5 PLAN



LONGITUDINAL SECTION THROUGH PORTAL

Fig. 12

East Portal



SECTION OF APPROACH SHOWING ELEVATION OF PORTAL

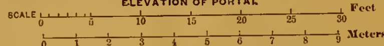
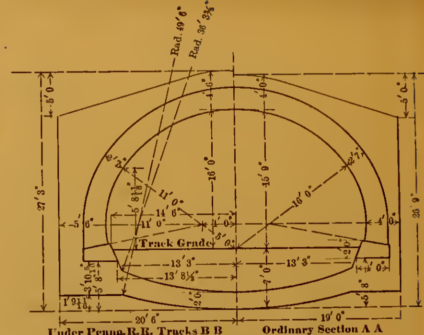
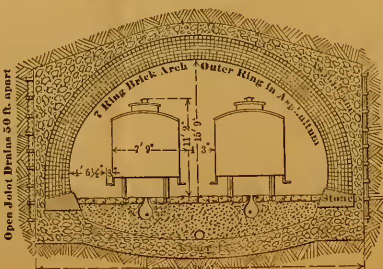


Fig. 13



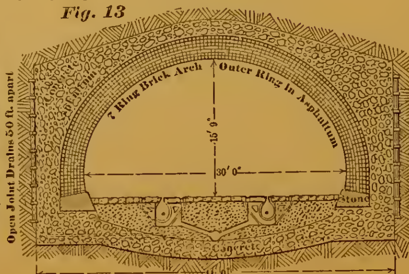
SECTIONAL DIAGRAMS

Fig. 10



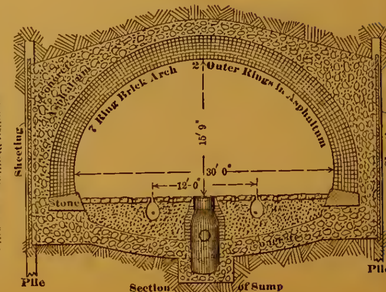
ORDINARY TUNNEL SECTION A A

Fig. 8



SECTION UNDER PENNA.R.R.TRACKS B B

Fig. 9



RIVER SECTION C C

Fig. 11

Bradley & Poates, Engr's, N.Y.

TYPHOID FEVER, AND THE EPIDEMIC AT IRONWOOD, MICH., IN 1893.

By E. A. Rudiger, Member of the Western Society of Engineers.

[Read June 6, 1894.]

The intimate connection between purity of water-supply and the health of cities and towns is now universally recognized. Many epidemics have been traced directly to the use of polluted water, and, where there is an outbreak of sickness in a community, the water used for drinking should be immediately examined in order to determine whether it has become contaminated.

The determination of the wholesomeness of a sample of water is no easy matter; taste and color are not infallible tests of its qualities. Chemical tests, although necessary, are not decisive. A microscopical examination is the only one which will show conclusively whether germs of disease actually exist in the water. A chemical examination will, however, show whether the water contains matter which will serve as nourishment for bacteria. Water that contains visible impurities, or that has a disagreeable odor or taste or color, may be rejected as unfit for use; but it may be comparatively harmless when compared to another that gives to the senses no outward indications of danger, but which is nevertheless contaminated by the germs of disease, and is therefore extremely dangerous to health. In general, however, a drinking water should be clear to the eye, pleasant to the taste, and free from offensive odor.

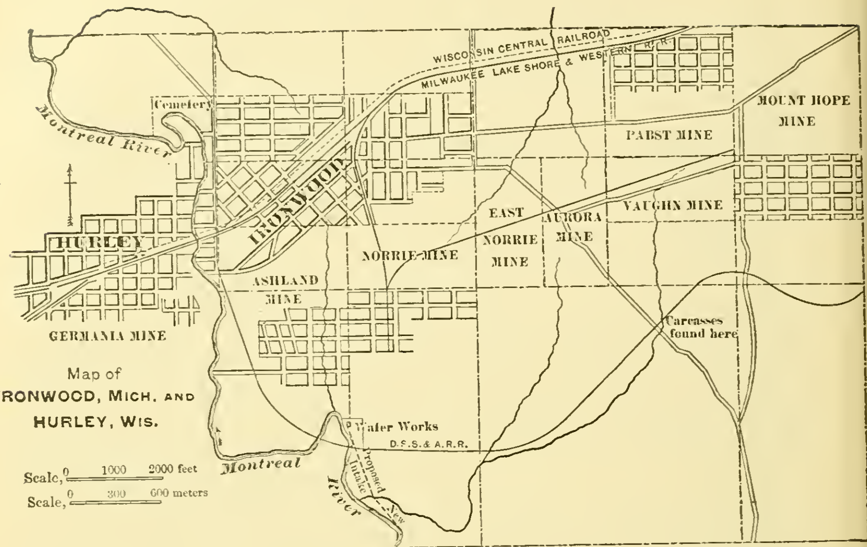
No perfectly pure water exists in nature. The waters of springs and wells, even though quite pure enough for drinking, usually contain mineral matters in solution. The water of shallow wells, obtained from surface gravels or the like, near large towns, is invariably much contaminated with organic matter, ammonia, nitrates and chlorides; the ammonia being obtained by putrefaction, and the nitrates by the oxidation of organic matter. The water which falls on the surface in such districts, percolates through the gravel, carrying soluble matter with it, including organic matter of the worst kind, which is present in large quantities near stables, privies, etc. Such water is totally unfit for domestic use, but is often in favor for drinking ; for, when fresh from the well, it may be cool, sparkling, and pleasant to the taste, owing to the decomposition and oxidation of the filth it contains. The excess of carbonic acid makes it sparkling, and the nitrates render it cool to the palate. These evil effects of surface drainage are often greatly

aggravated by the slovenly habits and the ignorance of the inhabitants, as shown in the disposal of refuse matters. Putrescible refuse from the house, excrement of man and beast, garbage of all kinds, and slop-waters, are allowed to lie exposed, decomposing in the open air, poisoning it and everything it contains; or are put into receptacles from which they are allowed to escape by seepage into the surrounding soil, and ultimately to reach the stratum of water from which the well is supplied.

Extreme care must be taken, where necessary, to prevent the surface drainage from reaching the wells, for contamination can occur without *visibly affecting* the quality of the water, and nothing may be suspected until sickness actually occurs. In an outbreak in one city, water from forty different wells was tested, and it was found that surface drainage had affected the water in every one. On an average, nearly 17 grains of injurious salts were found in the gallon of water. In another town, where only well water was used, sixty wells were examined, and every well was found to be contaminated. One well, used by 400 school children, was only 22 feet distant from the cesspool, and free ammonia and nitrous acid were found in excess in the water, which was used freely and pronounced excellent.

Streams, no less than well waters, are susceptible of contamination from excreta, and it has been satisfactorily demonstrated that these impurities cause outbreaks of typhoid fever, dysentery, and kindred diseases. In running streams such impurities appear to be eliminated from the water by the process of oxidation of the organic matter, and by settlement.

In May, 1893, the city of Ironwood, Michigan, a mining town in the Gogebic mining region, was visited by an outbreak of typhoid fever, which continued to increase in virulence until the end of June, at which time there were over three hundred patients sick with the fever, and about forty deaths from the disease had occurred. The city had suffered every year from fever, since the place was settled (eight years before), but not noticeably before the end of August or the beginning of September. Many of the wells in the town are notoriously subject to contamination from surface drainage, and all of them are shallow wells, sunk in the quicksand overlying the rock formation of the country. In all previous outbreaks, the disease was charged to the use of water from such wells. The unusual outbreak, so early in the season—practically on the breaking up of the winter, and occurring similtaneously throughout the city—led the city authorities to ascribe the cause of the epidemic to a common source. the water-supply of the Ironwood Water Works Company, whose works were built three years before. These works furnish water to the city of Ironwood, Michigan, of 12,000 inhabitants,



and to the village of Hurley, Wisconsin, of 3,500 inhabitants. The two towns are separated from each other only by the Montreal River, a small mountain stream, flowing almost due north at this point, whose source was in a series of small lakes, about fourteen miles south of Ironwood. The supply of the Water Company is taken from this stream, and the pumping station is located on its banks, where it enters the southern limits of the city. The water, like that of all streams in the lumber regions of Michigan and Wisconsin, is discolored by passing through cedar and tamarack swamps. It comes from lakes and springs; it is soft and flows rapidly in a rocky bed, and, with the exception of its color, has every requisite of a desirable and wholesome water-supply. The country through which it flows is entirely unsettled, with the exception of a small lumber camp of about half a dozen families, about eight miles above Ironwood, so that with this exception no typhoid contamination of the stream is possible, unless it come from the city of Ironwood itself. Chemical anaysis of the water had always shown that it was eminently suited to supply the city, and heretofore its quality had never been questioned. After the outbreak, another chemical analysis was made by Mr. E. P. Jennings, chemist of the Norrie mine, and this showed that the quality of the water had not deteriorated. The analysis gave the following result:

Free ammonia, ...	0.01 parts per million.
Albuminoid ammonia, ...	0.360 parts per million.
Chlorine, ...	$\frac{3}{10}$ grain per gallon.
Nitrates, ...	light trace.

In his report, Mr. Jennings says: The amount of free ammonia and chlorine is small, and does not indicate any contamination from decaying animal matter. The albuminoid ammonia is from the vegetable matter held in solution, and is common in all river and pond water of the Lake Superior country. The analysis is almost identical with those made a year ago.

While Ironwood was suffering so badly, the village of Hurley was almost entirely free from fever, and many were sincerely in doubt as to the responsibility of the Water Company for the epidemic.

One of the requirements of the company's franchise is, that filtered water shall be furnished for domestic consumption. During the previous winter the filter had been allowed to freeze and the pipes to burst, and, in consequence, the former superintendent was for some time unable to furnish filtered water. On the outbreak of the epidemic an investigation of the works was made by a committee of the citizens of Ironwood. The two stand-pipes belonging to the company were opened, and in each there was found a deposit, one or two inches deep, of decaying animal and vegetable matter, which (like that seen in the beds of streams) had been precipitated from the water pumped into them. The writer was afterwards engaged to take charge of the works and to make all improvements and repairs necessary to insure an uncontaminated water-supply.

The sanitary conditions affecting the health of the city and the nature of the water-supply used by the company were studied, and investigations were made to determine whether there could be found another and better supply sufficient for the present and future requirements of the city.

From a sanitary standpoint, the location of the city of Ironwood is a most unfortunate one, and the growth of the city has been so rapid that it has been entirely impossible to make proper provisions for protecting the health of the people. The site of the town, although a ridge, was a swampy forest eight years ago, before the discovery of the immense deposits of iron ore which were found there ; and it is divided into three different watersheds, all of which drain into the Montreal River. The southeastern part of the town, including the East Norrie, Aurora and Vaughn mines, is drained by a small stream, which discharges into the river about a quarter of a mile above the intake pipe of the Water Company. This part of the city is of recent growth, and, when the works were built, it was not foreseen that this little stream would become a menace to the Company's supply. The southwestern part of the town, including the Norrie and Ashland mines, is drained by a small water-course which discharges into the river about 300 feet below the intake pipe, and the entire northern half of the town is drained by streams discharging into the river north of and beyond the city limits.

Owing to the swampy nature of its site, Ironwood has always been unhealthy, and the trouble has been greatly aggravated by the extensive domestic use of water from shallow wells. The population is largely foreign, consisting of Swedes, Norwegians, Finns, Englishmen, Cornishmen, Irishmen, Frenchmen, Germans, Poles, Hungarians and Italians, and their habits increased the trouble. During the winter they dispose of all slops from the house by simply throwing them out of the back door on the snow, often only within a few feet of the well from which they draw their water-supply. Consequently, in May, when the snow melts, these accumulations of kitchen and chamber-slops and excreta are carried into their wells and into those of their neighbors. Many of these wells have such notoriously bad surroundings that they have been repeatedly closed by the health officer, but he does not seem to be clothed with sufficient authority to keep them closed, and they are soon in use again. In some localities sickness in as many as a dozen families has been traced to one well from which they drew their water. The filthy habits of these foreigners would naturally result in the pollution of all wells in their neighborhood when the snow melted, and would produce the contamination necessary for the outbreak of fever. These facts were ignored in accounting for the epidemic, and it was claimed that the condition of river water *must* be the cause; for it was argued that it was impossible otherwise to account for the simultaneous outbreak of the fever throughout the city. The city officials investigated the banks of the river for some distance above the pumping station, but discovered no source of contamination. An analysis of the water taken at the intake showed that the quality of the water was good. Several analyses were made at different times, and in no instance were typhoid germs found. In one analysis, where the water was drawn from a faucet after passing through a Buhring filter which had not been cleaned for six months, and which therefore was very foul, Prof. Victor Vaughn, of Ann Arbor University, found germs, with which he inoculated white rats, and which caused their death within twenty-four hours; but he stated that the germs were not those of typhoid fever.

Owing to the discoloration of the river water, a very strong movement was inaugurated to compel the Water Company to secure its supply from some other source. Springs immediately north of town; springs about eight miles north of the town, in Wisconsin; Lake Superior, distant about twelve miles north, in an air line; and, finally, Pine Lake, the source of the Montreal River, about twelve miles south, were all suggested. An examination, however, showed that neither of the supplies from springs was adequate, even if the quality of the water and the other conditions had been satisfactory. A supply from Lake Superior was out of the question, because the elevation of Ironwood is

over 1,000 feet above that of the lake, and the cost of pumping would have been entirely prohibitory. An examination of Pine Lake showed it to be a small deep lake, covering several hundred acres, but its waters have the same discoloration as the river water.

Railroad surveys show that Pine Lake has an elevation of 170 feet above the station in the center of Ironwood, and this is ample to convey the water of the lake to town by gravity flow. The stream, from the lake to Ironwood, flows rapidly, and, except for local pollution, the quality of the water when it reaches town should be fully as good as when it left the lake. Indeed, if there is anything in the theory of the self-purification of streams, the water ought to be better after its journey. This was proved to be the case. Samples of the water from the lake, and from the river at the point where it is proposed to locate a new intake pipe, were sent to Prof. Vaughn for analysis, and he reported that the quality of the river water was superior to that of the lake water.

Flowing through a thickly timbered country, entirely unsettled with the exception of the small lumber camp which was previously mentioned, and which will soon be abandoned because all the available timber there is cut, it seems self-evident that very little improvement in the quality of the water can be effected by taking directly from the lake instead of from the river, unless there exists some contamination which the Water Company cannot remove.

Evidently the contamination causing this epidemic was due to some local cause which had not existed before the season in question; and that cause must be either the lumber camp or the drainage from the city of Ironwood. The lumber camp had been visted earlier, and nothing had been found there which would affect the stream; hence, if the mischief came from the river water, only the city drainage could be held accountable. It was known, but not generally, that the drainage from the southeastern part of the town discharged into the river above the water-works, and this fact had been overlooked in the previous examinations. This stream was therefore examined, from its discharge into the river to its source in the town. The result was startling. At the upper end, inside the city limits, but in a part not yet built up, *six* decomposed carcasses of cattle and horses were found on the banks, or in the stream itself. It was said that these carcasses had been hauled there during the previous winter by one of the aldermen of the city, and, *ex-officio*, member of the Board of Health, who, by the way, died of typhoid fever about a week before this discovery.

Contamination of the water-supply had certainly been discovered and decided contamination too. It is a question, however, whether this was the cause of the outbreak of typhoid fever; some physicians claim that it was not necessarily responsible.

According to the germ theory, which recent investigations appear to confirm, typhoid fever is the result of a specific germ or bacterium, which grows and propagates itself in the human system, producing the fever. The bacteria are a group of low plants, so small as to be quite invisible to the naked eye, and, until within a few years, entirely unknown to man. So small are they, and so simple in their structure and activities, that it was not an easy task for scientific men to decide whether they belonged among animals or plants. It is now definitely settled, however, that they are plants and are closely related to the algæ. They vary much in shape, but, in general, are either spherical or ovoidal, like a billiard ball or an egg, rod-shaped, like a lead-pencil, or spiral, like a corkscrew. They appear under the microscope as pale, translucent bodies. Warmth, moisture, oxygen, and a certain amount of organic matter, are the simple conditions required for their activities. When the conditions are favorable, they increase to a degree limited only by their surroundings. So rapid is the process of reproduction that a single germ, by the process of growth and sub-division, may give rise to millions of similar organisms within twenty-four hours.

Many forms possess the power of living and multiplying so long as the proper conditions obtain, but when life, owing to some change in the surroundings, becomes no longer possible, the vital powers collect themselves in a little shining mass at one end of the bacterium, which then protects itself by a dense membrane, and in this form, which is called a spore, the individual can survive adverse conditions which, in the ordinary form, would have destroyed its life. Restore it to the needed conditions and the spore swells into a bacterium again and becomes the ancestor of new generations.

It was formerly believed that such low organisms as the bacteria could spring spontaneously into being whenever in nature the conditions were favorable; but this notion, which was shown to have depended on insufficient and crude observation, has long been given up. It is now believed that every living thing comes from some pre-existing living thing, be it man, beast, plant or cell, and that this principle holds true as well among bacteria as among more highly organized beings.

The typhoid germs are little rods or bacilli, considerably larger than those which cause tuberculosis. Genuine typhoid fever is caused by this particular germ and no other, and never in any other way. This germ is not known to grow, except in the human body, but it may remain alive outside the body, in water, or under other conditions; and it has been abundantly proven by careful experiments that it can remain alive for long periods when frozen solidly in a block of ice.

The most common ways in which the bacteria are spread are by the air we breathe, the food we eat and the water we drink. If any of

these necessities of life contain in them the living germs of the disease, there is liability of the infection of healthy or predisposed individuals. The probabilities are, however, that in the majority of cases typhoid germs are introduced into the system by drinking water which has been polluted by human waste containing them.

The typhoid germ can act on the system only after it has been taken into the stomach and has passed from it into the intestinal canal. In the intestines, if the conditions are favorable, it multiplies enormously. Some of the germs gain access to certain of the internal organs, but most of them either complete their existence in the intestinal canal or are cast out in the living condition with the diarrhœic discharges which always accompany the disease. Human excrement, therefore, is the necessary agent for the spread of the disease, as it is only by this means that the germs can pass from the body of the patient. It is said that human beings alone are affected by the disease, and they alone can be the source of infection.

The effects which these, as well as other disease-producing bacteria, may produce in the body, vary considerably under different conditions. Sometimes the general condition of the body is such that it seems to furnish very favorable soil for their propagation, or is specially vulnerable to their action. Sometimes the particular germs which gain access to the system seem to be especially virulent, perhaps from their inherent vigor, or from conditions which we know nothing about. In typhoid fever, analogous predisposing factors seem to determine that, when exposed to the same risk of infection, one individual may be attacked by the disease and another not. But in all these forms of bacterial disease the particular species of bacteria, belonging to each, must be present, predisposition or no predisposition, or the disease cannot occur.

Typhoid fever is often called a *filth disease*, and its occurrence has often been attributed to bad food, foul air, sewer gas and overcrowding. This is in a sense true, since these adverse conditions are apt to induce a state of the body which reduces its power of resistance; but no imaginable conditions could ever induce typhoid fever without the presence of the particular germ which causes it. The disease cannot spring up among any class or condition of people without the introduction of the germ from outside.*

According to the germ theory, the carcasses found along the banks of the small stream certainly contaminated the water-supply and rendered it dangerous for domestic purposes, yet it would not necessarily follow that they produced the typhoid epidemic. However, shortly after

* For these facts respecting bacteria and typhoid fever, the writer is indebted to Dr. Prudden's interesting little work, "Story of the Bacteria."

they were removed and buried, it began to be noticed that the fever was subsiding, and that the cases were growing less malignant, and within four weeks thereafter the number of cases had decreased to one-third of what they had been. Very few new cases were occurring, and most of them were directly traceable to the use of water from contaminated wells. It does not follow, however, that the decrease of the epidemic resulted from the removal of the carcasses, for other causes were also at work. Long before the fever had become so prevalent, many of the physicians of Ironwood had been very active in warning the people against the use of water from the water-works, and, on account of its color, only a limited number of persons had ever used it for drinking, but instead had bought spring water brought in carts, or had used well water. Since the beginning of the epidemic the health officers had also been very active in closing polluted wells and in cleaning yards, alleys and streets; and as a result of their efforts Ironwood was cleaner than ever before in its history.

The discovery of the pollution of the small stream shows positively the mistake on the part of the city in allowing the water-supply to be taken anywhere below the discharge of the drainage from any part of the city. The difficulty will now be remedied by extending a new intake pipe up the river about half a mile, to a point above where the small stream discharges.

The health of the city will not by any means be insured by this change in the water-supply. It will still be necessary for the city to thoroughly drain the ground on which it stands, and to carry off in sewers all the water which is discharged from the mines and which now forms many swampy places in town, detrimental to the general health. All wells containing only surface water must be condemned and filled in. Finally, the practice of throwing slops and refuse into the yards and alleys during the long winter months, must be rigidly forbidden. If these changes are effected, the health of the place will become normal, and its present reputation for unhealthfulness may in time become only a memory.

It may appear strange that, although the causes of the epidemic have existed since last winter, it did not appear until May. Isolated cases had occurred before—it is said, indeed, that the place is never free from the disease—but the number was insignificant until May. It must be remembered that the winter in this latitude is very long and very severe. During the winter of 1892–93, there was sleighing at Ironwood from November 7th until April 7th. Snow was deep in the woods until May 15th, and patches of snow were found even on Decoration Day. The melting snow carries the germs into the drinking water, and about two weeks after they enter the human system the fever appears.

A seemingly curious fact was observed in this epidemic. Certain nationalities seemed to be almost proof against attack and others were peculiarly susceptible to the disease. Poles, Italians and Hungarians are probably as filthy in their habits as any people in existence, and yet hardly one of them had the fever. Many cases existed among the Finns and Cornishmen, but the Swedes seemed the most susceptible to the disease, and most of the fatal cases occurred among persons of that nationality.

As a result of the investigations made, it appeared that the outbreak of fever was *not* due to the contamination of the river water, but rather to that of the wells throughout the city, when the snow melted in April and May, and washed into them the filth which had accumulated during the long and tedious winter. There is, however, a constant danger that the river supply will become polluted, and this danger will exist until the location of the intake pipe is made such that the water is taken from a point above where any city drainage discharges into it. Plans were made by the Company for this change, but negotiations were then completed for the sale of the works to the city, and owing to the delay in the transfer of the works, winter came on before the work was done. As soon as the city takes possession, it will undoubtedly complete the arrangements made, and insure an uncontaminated supply for the inhabitants.

The present company is formed by the consolidation of two companies, organized under franchises given by the city of Ironwood, Mich., and by the village of Hurley, Wis.; each system having been originally constructed independently of the other. Consequently, there are two pumping stations and two stand-pipes 30 feet in diameter and 50 feet high, one respectively in each place. The pipe system, for the two towns, consists of about fourteen miles of mains, with 156 fire hydrants and the necessary stop valves. Since the consolidation of the two companies the pumping station at Ironwood has supplied the water for the two towns, and since the city of Ironwood discharges its drainage into the river, it would be impossible for the Hurley pumps to supply uncontaminated water. For pumping into the mains the Ironwood station has two Deane compound, non-condensing pumping engines, each of one and one-quarter million gallons capacity per twenty-four hours. Besides, there is a three-quarter million gallon high pressure pump which draws the water from the river and discharges it into a Jewell gravity filter, from which it flows into a receiving well, 30 feet diameter, from which it is pumped to town by the compound pumps. Pumping operations are continuous, and the daily consumption is about 700,000 gallons, of which a large percentage is undoubtedly wasted, as the number of taps is only about 600. Alum is used in the filter as a coagulant, but

not enough is used to remove the color from the water, for this would require so much alum as to make the water hard. Possibly some other process of filtering and purifying the water might remove the color without affecting its softness. While the discoloration indicates no injurious quality in the water, it creates prejudice, and, if it could be removed, many would use the water who will not do so now.

APPENDIX I.

UNIVERSITY OF MICHIGAN.

Laboratory of Hygiene.

Report of the sanitary condition of water sent by John Evans, City Clerk, Ironwood, Michigan.

SOURCE OF WATER,

with remarks on the sanitary surroundings. Pine Lake, Ironwood, Mich.

PHYSICAL PROPERTIES.

Color—yellowish. Odor—musty. Reaction—neutral. Hardness—9.

CHEMICAL ANALYSIS, parts per million.

Total residue obtained by evaporation at 110° C.—550.
Residue after ignition, or inorganic matter in residue—470.
Organic residue, or loss by ignition—80.
Amount of Chlorine, calculated as Sodium Chloride—1.0.
Amount of Sulphates, calculated as SO_3—none.
Amount of Free Ammonia—0.018.
Amount of Albuminoid Ammonia—0.30.
Amount of Nitrates, calculated as N_2O_3—none.

MICROSCOPICAL EXAMINATION.

Description of deposit, if any, magnified 100 diameters.
Vegetable fibre and fresh-water algæ.
Same magnified 500 diameters. Same as above.

BACTERIOLOGICAL EXAMINATION.

Number of germs developed on a gelatine plate inoculated with one drop of water:

After 48 hours—150.
After 72 hours—500.

Remarks on kinds of germs observed: Micrococcus Lutens, Bacillus Albus, M. Aquatilis Albus.

INOCULATION EXPERIMENTS.

Kind of animal inoculated with the germs—White rat.
Method of inoculation—Injection into abdominal cavity.
Kind, amount and age of culture used—Beef tea, lc. c. 24 hours old.
Results of inoculation, negative.

CONCLUSIONS.

There is no evidence that this water can cause disease. The large amount of vegetable matter which it contains would, however, render it somewhat unpleasant as a drinking water.

V. C. Vaughn,
Director of the Michigan State Laboratory of Hygiene.

Ann Arbor, Sept. 1, 1893.

APPENDIX II.

UNIVERSITY OF MICHIGAN.

Laboratory of Hygiene.

Report of the sanitary condition of water sent by John Evans, City Clerk, Ironwood, Michigan.

SOURCE OF THE WATER,

with remarks on the sanitary surroundings—River Water.

PHYSICAL PROPERTIES.

Color— yellowish. Odor—none. Reaction—neutral. Hardness—7.

CHEMICAL ANALYSIS, parts per million.

Total residue obtained by evaporation at 110° C.—540.
Residue after ignition, or inorganic matter in residue—490.
Organic residue, or loss on ignition—50.
Amount of Chlorine, calculated as Sodium Chloride—0.50.
Amount of Sulphates, calculated as SO_3—none.
Parts of Potassium Permanganate reduced by the organic matter in the water – 0.125.
Amount of Free Ammonia—0.08.
Amount of Albuminoid Ammonia—0.35.
Amount of Nitrates, calculated as N_2O_5—none.
Amount of Nitrites, calculated as N_2O_3—none.

MICROSCOPICAL EXAMINATION.

Description of deposit, if any, magnified 100 diameters
Vegetable débris.
Same magnified 500, same as above.

BACTERIOLOGICAL EXAMINATION.

Number of germs developed on a gelatine plate inoculated with one drop of water:

After 48 hours—100.

After 72 hours—250.

Remarks on kinds of germs observed: Bacillus Fluorescens Liquefacious; Bacillus Albus, Micrococcus Acquatilis Albus.

INOCULATION EXPERIMENTS.

Kind of animal inoculated with the germs—White rat.

Method of inoculation—Injection into abdominal cavity.

Kind, amount and age of culture used—Beef tea, lc. c. 24 hours old.

Results of inoculation—negative.

CONCLUSIONS.

There are no pathogenic germs in this water and there is no reason for suspecting that, in its present condition, it can cause any disease.

V. C. VAUGHN,

Director of the Michigan State Laboratory of Hygiene.

Ann Arbor, Sept. 20, 1893.

APPENDIX III.

JOHN I. SOUTHER,

Analytical Chemist and Assayer.

HURLEY, Wisc., Feb. 14, 1891.

To the Ironwood Water-works, Hurley Water Co.,

No. 50 Broadway, New York City.

GENTLEMEN:—I enclose the report of the examination of a sample of water, taken by myself from your mains, February 13, 1891. The results are satisfactory, and I consider the water pure and wholesome. The exceedingly low amount of chlorides, taken in connection with absence of phosphates and nitrates, is conclusive evidence of perfect freedom from contamination.

Respectfully yours,

JOHN I. SOUTHER.

HURLEY, Wis., Feb. 14, 1891.

ANALYSIS OF FILTERED WATER, taken from the mains at Hurley and Ironwood by myself, February 13, 1891. Contains in one U. S. gallon of 231 cubic inches:

Free Ammonia	.054	parts per million.
Albuminoid Ammonia	.062	" " "
Organic and volatile matter	2.28	grains per gallon.
Inorganic	5.44	" " "
Chlorine	0.4	" " "
Calculated as Sodium Chloride	0.66	" " "

Phosphates	none.
Nitritis	none.
Nitrates	traces only.

Hardness, equivalent to 4.5 grains of carbonate of lime per gallon.

Appearance	clear.
Taste	none.
Odor	none.

To the Hurley Water Co., Ironwood Water-works Co.

JOHN I. SOUTHER, *Chemist.*

The undersigned physicians have examined the above analysis and cheerfully endorse the opinon expressed in the letter of Mr. J. I. Souther.

E. H. KELLY, M.D., Hurley, Wis.
L. C. SMITH, M.D., Hurley, Wis.

ASPHALT PAVEMENTS.

By S. Whinery.

[Read April 16, 1894, before the Engineers' Club of Minneapolis.]

The question of street paving is one of the most important that municipalities have to deal with. The amount of money already invested in street pavements is enormous, and yet none of our American cities are more than partially paved. The maintenance and renewal of pavements imposes upon municipal governments a very heavy tax, the amount of which is apparently not fully known or appreciated by even our most intelligent and best informed citizens. In the last census an attempt was made to ascertain and collect the statistics of street paving in American cities, but the effort seems to have resulted unsatisfactorily, and the information collected has not yet been collated or published. Judging from the reports issued by city engineers and city authorities, these officials themselves have not the information necessary to make a full and satisfactory statement. Some of the facts may be given, but they are presented in a rather disjointed way, and are generally incomplete and unsatisfactory.

I have before me, as I write, an unusually complete report recently issued by the city engineer of Toledo, Ohio. In it is given, in tabular form, a list of the streets in that city paved up to December 31, 1892. This table gives the names of the streets, and the limits between which each is paved, the linear feet of street so improved, and the width between curbs, as well as the kind of pavement used. As Toledo is a representative city of moderate size, having at the date named a population of one hundred thousand, it may be of interest to consider briefly some of the facts presented and to make some deductions therefrom. The length of paved streets in the city at that date was as follows:

Total length in miles of

Brick pavement	12.77
Monclova pavement	.71
Dressed Medina block pavement	2.23
Common Medina block pavement	18.11
Cedar block pavement	16.52
Asphalt pavement	12.22
Boulder (cobblestone) pavement	3.62
Limestone block pavement	.34
Flagstone pavement	.23
Telford pavement	1.12
McAdam pavement	12.30
Plank road pavement	7.86
Total	88.03

The report gives no data as to the cost of these pavements, but it is safe to assume that it was not lower than would be indicated by the prices that now prevail in that city for similar work. The average width of the paved streets seems to be about 33 feet, and consequently the average area of pavement per mile of street is about 19,000 square yards. Upon these assumptions the cost of all the city pavements aggregates \$2,364,660, which represents the amount the city and the property owners have invested in these improvements. The interest on this at 4½ per cent. amounts to the very large sum of \$106,410 per year. But this is not all. These pavements will all in time be worn out and require renewal. Assuming for each of these pavements the average life which experience shows to be probable, dividing the cost of each kind by its assumed life in years, and aggregating the results, it appears that the annual charge for renewal amounts to the sum of \$258,702, which, added to the interest charge named above, amounts to the enormous sum of over \$365,000 per year, or \$3.65 per capita of the inhabitants. The taxable property of the city in 1892 is stated to be \$43,317,830, so that the annual tax for interest and renewals amounts to \$8.43 per thousand dollars of taxable property.

While this matter is not exactly apropos to the subject of this paper, I introduce it in order to show the very great importance of the street pavement problem from an economical standpoint. It is safe to say that no subject, of anything like equal importance in municipal finances or municipal management, receives such meager attention from city officials and taxpayers. It must be remembered, further, that the question of cost and maintenance of street pavements is generally a minor consideration, since the question of economy in use is of far greater importance, as will be shown later on in this paper.

In view of these facts, it must be evident that the matter of paving the streets of any city is of such financial and industrial importance as to merit the most careful and searching study. All the elements that enter into the problem should be considered, not only in a general way, but with reference to the conditions and environments of each case. These often differ greatly in different cities. The subject should be studied, not in the light of theory alone, but in that of the experience of other cities, for this is often of the greatest value.

Coming now to the special subject of this paper, it is proper to begin with a description of the materials used in the composition of asphalt pavements. These are: Sand, pulverized carbonate of lime, residuum oil, and asphalt.

The sand used is ordinary silicious sand. That considered best for the purpose is quite fine, the grains being of various sizes, so as to make a body with as small a ratio of voids as possible. The grains should be sharp, since the asphaltic cement adheres best when this is the case.

The pulverized carbonate of lime is simply ordinary limestone, ground to an impalpable powder.

The residuum oil, as its name implies, is what remains in the process of refining crude petroleum after the lighter oils, such as naphtha, kerosene, and the heavier oils used for lubricating purposes are removed. It should have a specific gravity of from 0.9 to 0.92 (equivalent to 18° to 22° Baumé), and a fire test of not less than 400° Fahrenheit, and should be reasonably free from coke and other impurities.

The asphalt is the most important material in the composition of the pavement. Asphalt is the name given to a natural mineral pitch, which is found widely disseminated over the earth and existing in almost inexhaustible quantities in a number of countries. It belongs to the great family of the hydro-carbons, under which name are comprised so many of the useful minerals employed in the industrial arts, among them being anthracite and bituminous coal and petroleum. It has been known from the earliest historic times. We are informed in the Bible that it was used in pitching Noah's Ark to make it water tight, and was later used as a cement in constructing the walls of Babylon. Historic references to it are found in the literatures of most countries since that period. In the Greek language and literature it was called "Asphaltos," and this name, with slight modifications in sound and spelling, is found in most modern languages. Its physical and chemical properties may be described as follows: Asphalt, as usually found, is of a dark brown or glistening black color. It varies in hardness from a viscous liquid to about 3½ on the scale of Dana. The streak is almost uniformly brown, sometimes brownish-black. Before the blow-pipe the solid varieties are quickly melted, and all are evaporated and burned, leaving, as ash, the organic and inorganic impurities, which are usually found in it in smaller or larger quantities. It is readily distinguished from coal-tar pitch and other artificial bitumen by the absence of the pungent smell which is given off from these substances, especially when heated. It is not a mineral of distinct chemical composition. Generally, it is a compound consisting of various hydro-carbons, which can be separated from each other only with great difficulty. Its typical chemical composition when pure may be stated to be: carbon, 82 per cent.; oxygen, 7 per cent.; hydrogen, 10 per cent.; nitrogen, 1 per cent.; but there are often found in it other minerals which may be called impurities. The most common of these is sulphur, which sometimes constitutes from 1 to 10 per cent. of the whole. Varieties from different localities seldom, if ever, agree with each other in chemical composition. Asphalt may be separated, with more or less readiness, into several different substances, the chemical composition of which differs materially. The early chemists called these products "Asphaltine," "Petroline,"

"Retine;" and there were one or two others based upon the proportions of the mass which were found to be soluble in various substances. It is very questionable, however, whether this division is well founded. Chemists have differed widely as to the quantities of each of these so-called elements found in samples from the same locality. It is undoubtedly true, however, that nearly all asphalt may thus be separated into a number of substances which differ somewhat in chemical composition, and widely in their physical properties, and which have an important influence on the value of the asphalt for the various industrial purposes.

Under the head of "Asphaltine" has been classed that part of the asphalt which is soluble in chloroform and bisulphide of carbon, and not in ether or naphtha; and under the head of "Petroline" has been classed that part which is soluble in ether and naphtha. Under the name of "Retine" was classed that part which is soluble in alcohol.

Considered with reference to the industrial uses to which asphalt is generally applied, it is found that asphaltine is hard and brittle, requires much higher heat to melt it, or burns without becoming melted, and has very little, if any, of the adhesive qualities which make asphalt useful as a cement. Petroline is softer than asphaltine, becomes fluid at a lower temperature, and has great adhesive or cementitious qualities. It is the valuable part of asphalt for most industrial work. Retine partakes of the character of vegetable resin, and is not considered as adding anything to the value of asphalt in practical use.

More recent physical examinations incline investigators to class all these constituents under two heads only, the active and the inert; the inert material being the hard and brittle part which is not readily melted by heat, and which adds nothing to the cementitious properties of the asphalt; while the active element is that part which is readily melted by heat, is readily soluble in ether or naphtha, and is highly adhesive and cementitious. The ratio in which the active and the inert constituents are combined is a proper index of the value of the material for use as a cement; but for other industrial purposes, such as insulating electric wires, etc., it has no practical value, for the active and the inert constituents appear to be equally good as non-conductors.

It is found that the chemical analysis of asphalt is not a reliable indication of its value as a cement, since asphalts having practically the same chemical composition, differ within wide limits as to their physical properties, and particularly as to their tensile and compressive strengths. The writer has lately made a series of investigations to determine the tensile and compressive strengths of three varieties of asphalt, with the view of determining the value of each for paving purposes. It is well known to civil engineers that the strengths of

hydraulic concretes, when made under similar conditions and with like ratios of materials, are to each other generally as the strength of the hydraulic cement used. This rule is not strictly accurate, but is a safe general guide. It is evident that the strength of a concrete can not be much greater than that of the cementing material in its composition. The composition for the wearing surface of an asphalt pavement being practically a concrete made up principally of silicious sand cemented together with asphalt, it is safe, within proper limits, to conclude that the strength of the cementing material is a correct measure of the strength of the resulting compound; or, in other words, that the strengths and serviceabilities of pavements made with the three varieties of asphalts, would be, at least approximately, as the relative strengths of the asphalts themselves. The results arrived at are as follows:

COMPARISON OF ASPHALTS.

	Pitch, Lake Trinidad.	Bermudas.	California.
Average crushing strength of refined asphalt at 20° F. in pounds per square inch	1,399.	661.	1,000.
Average tensile strength of refined asphalt at 52° F. in pounds per square inch	290.	125.	182.
Relative brittleness at 50° F., Pitch Lake Trinidad being unity	1.	1.9	1.3

An asphalt pavement may be briefly described as a street pavement of artificial sandstone, composed mainly of quartz sand cemented together with asphalt, resting upon a proper foundation, and possessing the quality of great endurance under the travel to which streets are subjected; together with other qualities that are considered of great value from an industrial and economic point of view.

The refined asphalt is melted and brought to a temperature of about 300° Fahrenheit. About 17 per cent. of residuum oil is then added to the asphalt, and the whole is thoroughly mixed. The office of the residuum oil is to soften the refined asphalt, and to bring it to that consistency in which its cementing capacity is greatest. The thorough mixing of the oil and asphalt is important. Formerly this was accomplished by mechanical mixers, but it was found that it could be most thoroughly done by blowing air into the bottom of the vessel in which the mixture is heated. The air, rising through the fluid mass, keeps it in constant motion, thus securing the most perfect mixing of the two materials.

The resulting composition of asphalt and oil is called *asphaltic*

cement, and is ready for use in the pavement. The selected sand is also dried and heated to a temperature of about 320° F. in revolving drums placed in a furnace suitable for the purpose, and all grains, pebbles, etc., above a given size are removed by screening. When all is ready, the proper quantity of hot sand for one batch of paving material is accurately measured in an iron box, the necessary amount of pulverized limestone is added, and the whole is taken to the mixer. At the same time the required amount of asphaltic cement is accurately weighed out, and all the materials are simultaneously poured into a mechanical mixer with two sets of interlocking revolving blades, which very thoroughly mix the materials with each other in about one minute.

The composition of the complete pavement mixture is not constant, but varies with the character of the sand used, the climate in which the pavement is laid, the character and amount of travel to which it is exposed, and other minor conditions. The quality of an asphalt pavement depends largely on the knowledge and good judgment of the person who makes up the mixture used, and his ability to make a pavement suited to the service required of it.

The following may be regarded as a typical composition:

Sand, percentage by weight	77
Pulverized limestone, percentage by weight	10
Asphaltic cement, percentage by weight	13
	100

When the mixing is completed, sliding doors in the bottom of the mixer are opened, and the material drops out into the carts or wagons which carry it to the street. In this condition it is a loose pulverulent mass, each grain of sand being very completely coated with the asphaltic cement.

In the meantime, by grading, rolling and properly preparing the foundation, the street has been prepared to receive the asphalt surface. Of this part of the work more will be said hereafter. The asphalt is laid upon the foundation in two coats or layers. The first, called the cushion coat, is made about 5 per cent. richer in asphalt than the surface coat, and is from one-half inch to three-fourths inch thick. The material is brought to the street in carts or wagons, dumped upon the prepared foundation, carefully distributed and evenly spread over the surface with shovels and rakes, and compressed, first by a hand roller and then by a steam roller weighing from five to ten tons.

The second, or surface coat, is applied in the same way, except that more care is taken to rake out the material to a uniform thickness so that after rolling the surface shall be as smooth and regular as possible; and the rolling is continued as long as the roller will make the slightest

impression on the surface; or, in other words, until the material is compacted to the greatest possible degree. It is a fact generally known among engineers that dry sand cannot be much consolidated by direct pressure, whereas it may be considerably compacted by other methods. So the sand which comprises the bulk of an asphalt pavement cannot be properly compacted by direct pressure, but requires the rolling or kneading action of the heavy roller. The lubricating quality of the warm asphalt aids in this action, so that under the roller the particles of sand are wedged together and the finer particles worked into the voids, until the mass becomes more dense than dry sand alone could be made. This is proved by the fact that if all the bitumen be extracted from a fragment of pavement of known volume, it is found to be quite impossible to reduce the dry sand obtained to as small a volume as it occupied in the pavement.

The asphalt surface thus laid is found to resist admirably the abrading action of travel, but alone it has not very great strength or supporting power. It is, therefore, necessary that it be laid upon a foundation having sufficient strength to support the heaviest loads to which the pavement shall be subjected. In general, a pavement has two distinct functions to perform: first, it must have sufficient strength to support any load that may be brought upon it by the proper and legal travel over the street. Second, its surface must be able to withstand the wear or abrasion of the wheels of vehicles and of the feet of horses. While both functions are equally important, their offices are quite distinct.

The ideally perfect pavement should have a foundation that is permanent and practically indestructible by the legitimate service of the street. When once in place, protected as it is from the wear of travel, it should be good for a century of use. The wearing surface will in time be worn out, for we have as yet discovered nothing that will indefinitely resist the wear of travel. This wearing surface should be of such a character that when worn out it may readily be renewed at a reasonable cost.

The ideal foundation for an asphalt pavement is a bed of hydraulic concrete extending from curb to curb, and having sufficient depth or thickness to bear any proper load to which the pavement may be subjected. This thickness will be determined by the character of the travel to which the street is likely to be subjected, and to some extent by the nature of the soil upon which it rests. In the case of ordinarily good soil, it has been found that a thickness of six inches is ample for streets having the heaviest travel. For suburban or residence streets, experience has shown that four inches of good concrete will give very satisfactory results.

The concrete for the foundation should be of first-rate quality. The mortar should be composed of two parts of clean sharp sand, and one part of the best natural or domestic cement, or three parts of sand and one part of good Portland cement. The broken or crushed stone should be hard and durable, free from dirt and rubbish, and should be passed over screens which will take out all fragments under the size of a grain of corn, and those over 2½ inches in any direction. Many engineers specify that all fragments under ¾ inch in size must be screened out and rejected, but in my opinion this is a mistake. The ideal concrete is composed of the largest possible ratio of solid stone, with just enough mortar to completely fill the voids and cement the stone together. This ideal will be most nearly realized when the masses of broken stone are so assorted in size that the voids between the larger pieces will be filled by smaller fragments, the remaining voids by still smaller fragments, and so on. Of course, all very fine particles and dust must be excluded, unless the ratio of sand to cement be reduced, since the use of such fine material is equivalent to the introduction of that much more sand. Furthermore the amount of smaller fragments of stone should not be greater than is required to fill the voids between the larger masses; but this will very seldom be the case with good stone, crushed in the ordinary way.

The concrete, when mixed, is placed on the rolled surface of the street in a layer of such depth that after being well rammed it will have the requisite thickness. Its upper surface must be graded to a plane parallel with the surface of the finished pavement, and sufficiently below it to allow room for the specified thickness of asphalt. It should be allowed sufficient time to set thoroughly, so that it will bear the weight of the roller without injury, before the asphalt surface is applied. The process of setting proceeds very slowly after the coating of asphalt is applied, and it is not completed for more than a year thereafter.

While a concrete foundation is the one generally used for asphalt pavements, it is not always required. It is found by experience that an old granite block or cobblestone pavement, if it is in fairly good condition, and if it does not have to be disturbed for the purpose of building sewers or laying pipes, forms an admirable foundation for the asphalt surface. Of course, the surface of the old pavement must conform closely to the proposed grade and cross-section of the new pavement. Many miles of granite block pavement are being thus utilized as foundation for asphalt pavement in the city of New York, and, to a smaller extent, in other cities. Even a thoroughly compacted macadam road can be thus utilized, if the macadam extends from curb to curb and has the proper depth, grade and cross-section. Where such old pavements can be utilized, the cost of the asphalt pavement is materially reduced.

Civil engineers, whether engaged in municipal work or not, are generally acquainted with the most approved methods of constructing the several kinds of street pavement, and there is not much difference of opinion on this point. When, however, the question of the comparative durability of pavements, or their relative economy in use, or their relative desirability, is to be considered, there is a great diversity of opinion and room for wide discussion. This diversity of opinion results partly from difference of view as to what qualities are essential in the ideal pavement, and partly from the absence of data upon which to base sound opinions. It is, therefore, to these parts of the subject that I propose devoting the remainder of this paper.

What constitutes an ideal pavement for the roadway of city and village streets, and what are the elements that go to make it up? Unfortunately we have not yet discovered a street pavement that possesses in the highest degree all the desirable qualities. The perfect pavement, it is safe to say, is an ideal which will never be even approximately attained, because some of the qualities required of a perfect pavement are antagonistic to each other. For instance, the quality of perfect durability would necessitate the use of a material between which and the shoes of horses and the wheels of vehicles there would be absolutely no friction, since friction and abrasion are necessary functions of each other. But a pavement from which should be eliminated all friction would manifestly afford no foot-hold for horses drawing loads. We can, therefore, estimate only the *degree* to which each kind of pavement approximates the perfect ideal. So many elements enter into this estimate that it requires the most careful judgment, the nicest balancing of the relative values of these elements, and the most careful summation of the whole to arrive at correct conclusions.

Opinions will vary not only as to the weight to be attached to each element in the problem, but also as to the degree in which each kind of pavement possesses those elements.

If an absolutely perfect pavement were brought to the attention of the public, plenty of people would doubtless consider it as possessing grave faults. It is pretty safe to say that if we retain our critical dispositions in heaven, there will be much adverse criticism of the golden pavements of the Celestial City.

It would be quite impossible to go fully into the question in a paper like this, and I have too much consideration for your comfort to attempt it.

A practically perfect street pavement would possess the following qualities, which I have placed in the order of what seems to me to be their relative importance:

(1) It must be unobjectionable from a sanitary point of view.

(2) It must be comfortable to use and pleasing in appearance.

(3) It must possess the highest degree of economy in use.

(4) And last, as of least importance; its first cost and its cost of maintenance must be reasonable.

It will at once be noticed that this order reverses the rank in which these qualities have heretofore been generally placed with regard to their relative importance. It is not long since the qualities of low first cost and great durability were regarded by nearly all, as they are yet by many, as the first essentials in a street pavement, and other qualities were considered of secondary consideration; but in recent years there has been a very significant change of opinion on this point among physicians and sanitary engineers, and to some extent among the more intelligent laymen.

The recent rapid strides in the domain of sanitary science have made it clear that the most important conditions of urban life are those that relate to the health of the people. It is not surprising, therefore, that there is a growing tendency, not only among sanitary authorities, but also among the better part of society at large, to subordinate everything else to the question of correct sanitation. Indeed, the idea is being advanced that a municipal government that does not place before all other questions that of correct sanitation and careful regard for the health of the people, is guilty of criminal negligence. From this point of view the sanitary qualities of the several kinds of pavement are seen to be of the first importance. The perfect pavement, from the sanitary point of view, must possess the following qualities:

(*a*) It must not be subject to organic decay or decomposition, for it is well understood that the products of the decomposition of organic matter, if not in themselves injurious, may be the vehicle or menstruum for the propagation and dissemination of disease-producing germs.

(*b*) It must be impermeable and none-absorptive, for, if it is otherwise, the liquid organic refuse of the street will be absorbed by it, or will pass through it into the soil below, which, in time, will thus become so polluted as to be dangerous to the public health.

(*c*) It must admit of being readily cleaned. To comply with this condition, the surface must be hard and even, and there must be as few cracks or joints as possible, for these catch and hold the street dirt, and render it more or less difficult of removal.

(*d*) There are some other qualities connected with the sanitary value of a pavement, which, while they are not directly related to the production of disease, are yet of sufficient sanitary importance to be referred to here. The most important of these is noiselessness. Physicians are practically agreed that noisy pavements are an indirect cause of disorders of the nervous system, particularly among persons of delicate and sensitive organization.

I am well aware that in placing comfort in use, and good appearance, before more utilitarian considerations, I subject myself to criticism. I believe, however, that while the public is not yet prepared to fully accept this view, the time is not far distant when it will be not only generally accepted, but adopted in practice. While we are still an intensely utilitarian people, we are growing to attach less importance to utility of a lower order, and to demand that our comfort and our æsthetic tastes shall be considered, as well as our bare necessities. Perhaps this idea is best illustrated in the modern residence, which is no longer merely a shelter from the elements, but a wonderful combination of everything that contributes to the comfort and to the artistic tastes of the owner or occupant. Not only is this true of the homes of the wealthy; it is becoming equally true, if in a less degree, of the cottage of the workman. We beautify our grounds and lawns, and we are no longer satisfied with the rough stone or wooden sidewalks which serve every necessary purpose. Even our stables, as they are often designed and constructed, are models of beauty and convenience, and of comfort for the beasts that occupy them. Beautiful lawns and other improvements look incongruous when they are bounded by streets covered with a pavement which, by reason of inherent defects, or of neglect, is ragged, or decayed, or unclean, a source of disease and discomfort to those who use it or occupy buildings facing it, and a blemish in an otherwise attractive and beautiful landscape.

Why should not our ideas of comfort and comeliness be carried out in the adjoining street as well as in and about our homes?

The elements which render a street pavement acceptable in this respect are a smooth surface, noiselessness and cleanliness.

Third in importance among the requisites of the perfect pavement, I place economy in use, and under this general head may be named the following qualities:

(*a*) The pavement must offer a minimum resistance to the traction of vehicles. The importance of this requisite is often overlooked. Writers upon the subject of road improvement have again and again called attention to the importance of this quality as applied to common roads, and have taken the position that the annual loss to the country, brought about by its absence, runs up into millions of dollars; and, while more careful investigation shows that their estimates are greatly exaggerated, there can be no doubt that there is a substantial basis of truth for their assertions.

It may be conclusively shown that on streets of moderately heavy travel the difference between good and bad pavements in the cost of transportation is a factor so large that the question of the first cost of the pavement, or of its durability, is of comparatively small importance.

(*b*) Another point to be considered in estimating the relative economy of different pavements, is the amount of wear and tear upon vehicles using them. This matter is largely overlooked by the public at large. Unfortunately, we have very little exact information upon this point, though it is of such importance as to deserve careful investigation. Suppose, for example, that a good brick pavement is one-fifth less destructive to vehicles than an ordinary granite block pavement; or, in other words, that a vehicle which would endure four years' constant service on the granite pavement would last five years on the brick. Suppose, further, that the average cost of the vehicle is $120, which is $30 per year if distributed over four years, or $24 per year if distributed over five years. The difference, $6 per annum, will represent the saving in the wear and tear of the vehicle. Assuming further that 10,000 vehicles are regularly in use on the streets of the city, the saving would be $60,000 per year. This sum, capitalized at 5 per cent., is equal to $1,200,000. In other words, considering this element of economy alone, the city would be justified in paying $1,200,000 more to pave the streets with brick than to pave them with granite. Every one who carefully considers this matter will, I think, agree with me, that all the above assumptions are well within the reasonable limit, and yet the conclusions are astounding. The difference in favor of asphalt pavement in this respect is still more important and striking.

(*c*) The relative cost of keeping the pavement clean is another item to be considered in this connection. Upon this point, fortunately, we are not compelled to reason entirely from assumed facts. It is, for instance, a well-established fact that an asphalt pavement can be kept clean for 20 per cent. less cost than granite, or ordinary wooden block pavement, and for 10 per cent. less than ordinary brick pavement. The average cost of cleaning 1,000 square yards of granite pavement is about 40 cents each sweeping. If the streets are swept 100 times each year, the annual cost at this rate is $40.00 per 1,000 square yards, and if a city has 2,000,000 square yards of pavement to be cleaned, the cost will be $80,000 per year. If asphalt is substituted for granite, the cost of cleaning would be 20 per cent. less, or $64,000 per year, a saving of $16,000 per year; and, if we call the life of the pavement fifteen years, the whole amount saved in that period will be $240,000.

(*d*) Another element in the problem of the relative economy of different pavements relates to the effect upon horses traveling over the street.

The ordinary earth road, when dry and in good condition, very nearly approaches perfection in this respect, and it may be assumed as the standard with which street paving should be compared. In this respect, especially, we find the requisites of the ideal pavement dia-

metrically opposed to other essential qualities. To be least injurious to horses a roadway must be soft and yielding; but this quality can be secured only by sacrificing other qualities of greater importance, as ease of traction and durability. If the earth road represents the ideal in this respect, a granite block pavement on a rigid foundation will represent the opposite extreme, it being without doubt more injurious to the feet of horses than any other pavement.

I come now to the element which I have placed in the list as being of the least relative importance. About this there is room for much discussion, and there are many open questions to be settled.

The perfect pavement should be reasonable in first cost, inexpensive to keep in repair, readily and economically renewed when necessary, with the least possible inconvenience to those who use the street. It requires but little careful consideration to convince us that these requisites must be considered together, and in connection with each other. The question of constructional economy is not: which pavement is cheapest in first cost? nor is it: which will endure longest under given conditions? but: which pavement may for the least money be constructed and maintained in first-class condition for a long period of years, and left in like good condition at the end of that period. This branch of the subject may be divided into the following heads:

(*a*) First cost.
(*b*) Interest on investment.
(*c*) Cost of maintenance.
(*d*) Life of the pavement.
(*e*) Cost of renewal.
(*f*) Facility of renewal.

The first cost of the several kinds of pavement varies considerably in different cities with the cost of supplies and labor. As I have already observed, the facts relating to this branch of the subject are quite well known, or readily obtainable, and I need not detail them here.

To the second item, interest on investment, I wish only to call attention as an element of importance in dealing with the question of the cost of pavements.

When we come to consider the cost of maintenance of any pavement, we are met by the fact that we have very few data from which to reason, or upon which to base conclusions. It would seem that but little care has been taken to ascertain and record the amount of money spent on those slight repairs which every pavement will require during its lifetime. Furthermore, it is well known that there are constantly being made, upon old pavements, expenditures which should properly be charged to reconstruction, since the pavement should be considered as worn out and needing renewal when these repairs are made. This at

once raises the question: When should a pavement be considered as worn out? In general, it may be answered that a pavement is worn out when the cost of replacing it with a new pavement is less than the increased expense which its further use entails. This expense includes not only the cost of the repairs required to keep it passable, but also the money value of the extra power required to haul loads over it, the increased wear and tear to vehicles and horses, and the loss of time and the personal discomfort its use entails. If these items of expense were given proper consideration many an old pavement now in use would be promptly condemned. The item of maintenance should, therefore cover only that period in the life of a pavement, from its construction to the time when it should be wholly discarded and renewed.

In the Report of the Engineer Department of the District of Columbia for the year 1893, it is stated that the cost of maintenance of all the bituminous pavements of that city, after the expiration of the five years' guaranty, has averaged about 3 cents per square yard per year. The area of pavement from which this average was deducted, and upon which the repairs were made, was, in 1884, 812,070 square yards, and at the time of the report that area had increased to 1,396,386 square yards. But as the account covers repairs to a very large amount of coal-tar pavements, laid when these were popular in Washington, the statement is not a reliable indication of the cost of repairing the genuine asphalt pavements.

The cost of repairs to the wooden pavements of London is reported by Col. Haywood to vary from 59 to 80 cents per square yard per year.

It is stated that the cost of maintenance of granite block pavements in London varies from 6 to 19 cents per square yard per year.

The cost of maintaining macadam boulevards in this country seems to vary from 6 to 22 cents per square yard per year. It must be remarked, however, that all these data are indefinitely stated and therefore unreliable, and the same remark applies to nearly all the existing data on the subject.

In considering what is the life of a pavement, it is to be borne in mind that in this regard pavements must be divided into two general classes: those that are and those that are not subject to natural decay. Pavements not subject to natural decay are in time worn out by the destructive effects of the travel to which they are subjected, and the correct measure of their life is the number of units of travel they will endure before requiring renewal.

The life of pavements subject to natural decay is measured in the same way, provided the volume of travel is sufficient to wear them out before the effect of natural decay comes in to assist in their destruction. These principles seem simple and self-evident, and yet they are constantly disregarded not only by laymen, but by engineers.

We are constantly hearing it stated that some pavement on a street named has been down ten, or twelve, or fifteen years and is still as good as new, but those who make these statements seem to think it unnecessary to give any data as to the number of tons of travel it has carried in that time. They omit the only information by which the true durability of the pavement might be judged.

It is very unfortunate that so little has been done by city engineers in the way of ascertaining and recording the statistics of travel on paved streets. If this were systematically done for a considerable period, on streets paved with different materials, we would be able in time to say that a pavement of granite, or brick, or asphalt, or cedar blocks, is capable of carrying a given number of tons of travel before being worn out, and we could then deal intelligently with the question of the life and endurance of each pavement. There are, it is true, some data of this kind in existence, but they are too incomplete and fragmentary to be of much value. Writers upon the subject are constantly making statements with reference to the probable life of various pavements which, if not mere guesses, are based on the flimsiest of data. As an instance, I may mention that one able writer, from tests made of certain paving bricks, argues that a pavement made of them would last thirty-two years upon lower Broadway, New York, where the hardest granite is destroyed in about seven years. Such a statement would be amusing if it were not likely to be seriously misleading to honest laymen seeking information on a very important question.

The company with which the writer is connected has been for several years compiling a complete census of the travel over a considerable number of streets, paved with various materials, in quite a number of cities, and we hope in time to be able to form a pretty correct idea of the life of the several kinds of pavement in common use, measured in tons of travel per square foot of surface. Some of the results already arrived at are interesting and valuable. As an instance I may name Race Street in Cincinnati, Ohio, which sustains the heaviest travel in that city, and which carries an average of 203 tons per square foot per day. Over 5,000 vehicles and over 7,000 horses pass a given point each day. The pavement is now 7½ years old, and in that time it has carried over 550,000 tons per square foot of surface. The pavement is still in good condition.

In reference to the cost of renewal of pavements it is not necessary to go into details. It depends not only on local condititions and upon prices of material, but to a large extent on the character of the original pavement. In the case of pavements having a permanent foundation of concrete or other material, the cost of renewal will of course bear a smaller ratio to the original cost than where renewal means practically

replacing the whole structure. The renewal of the surface of an asphalt pavement, including the removal of the old surface, will not generally exceed $2.00 per square yard.

Having now glanced at the qualities which should be found in the practically perfect street pavement, and at some of the principles by which those qualities should be judged, let us consider briefly to what extent the asphalt pavement fulfills the requirements and how it compares with other kinds of pavement when judged by the standard we have set up.

In regard to sanitary requirements it will, I think, be conceded that asphalt pavement closely approaches perfection. It is impervious to water, and consequently it can not absorb, or transmit to the underlying soil, the filth of the street. Its smooth surface makes it possible to keep it as clean as the floor of a house, and, next to wooden blocks, it is more nearly noiseless than any other pavement.

In the matters of comfort in use and good appearance it admittedly has no equal. In those qualities which make a pavement economical in use it stands first, with the one exception, that a wooden block pavement is easier upon the feet of horses.

I think there can be no question as to the fact that the saving in wear and tear of vehicles alone overbalances any difference there may be in favor of other pavements in the item of first cost and cost of maintenance, and I believe every one who investigates the subject will be forced to admit this fact. Of the great saving in the power required to haul loads over an asphalt pavement, as compared with that required on other pavements, it is only necessary to say that on a level asphalt pavement a horse can draw approximately 45 per cent. more than on a brick pavement, 130 per cent. more than on the best granite block pavement, 210 per cent. more than on the best wooden block pavement, and nearly 700 per cent. more than on a cobble-stone pavement. Upon this point I cannot do better than quote so eminent an authority as Rudolph Hering, C.E., who says:

"If one horse can just draw a load on a level road on iron rails, it will take one and two-thirds horses to draw it on asphalt, three and one-third on the best Belgian block pavement, five on the ordinary Belgian pavement, seven on good cobble-stones, thirteen on bad cobble-stones, twenty on an ordinary earth road, and forty on a sandy road. Therefore, a city paved with sheet asphalt will save to itself and its citizens from 200 to 300 per cent. of the cost, to it and them, of transporting passengers and goods, as compared with a city paved with blocks. This saving will in a large city amount to thousands of dollars daily, and the yearly aggregate would doubtless be large enough to pave the city. It is a saving, too, that affects every person residing or owning property in the city."

I have already stated that an asphalt pavement can be kept clean for 20 per cent. less cost than any other pavement and that the saving on this account amounts to a very important sum of money, where the area to be cleaned is considerable.

When we come to consider the item of first cost of the various pavements, we cannot speak so confidently, since, as before stated, the cost varies greatly in different cities. It is safe to say generally that granite block pavement is the most expensive, asphalt next, brick pavement next, and cedar block, as ordinarily laid, the cheapest of all.

In the item of cost of maintenance during the proper life of the pavement, it is probable that granite is least expensive, brick next, asphalt next, and wooden block last, or most expensive, when figured upon the basis of cost per square yard per year. But, as already stated, we lack the data to determine this item with even approximate correctness.

As regards the relative durability of pavements, the evidence in our possession seems to indicate that upon a city street having travel to the amount of 100 tons per square foot per day, we may reasonably expect the life of pavements to be about as follows:

Granite block on concrete foundation	20	years.
Asphalt	15	"
Best paving brick on concrete foundation	9	"
Cedar block pavement	6	"

As before stated, the true way to compare pavements with regard to the cost of construction, cost of maintenance, durability, and cost of renewal, is to ascertain the whole cost (including interest) of constructing, maintaining and renewing each for a period of years equal at least to the life of the most durable of the pavements to be compared, and divide that whole cost by the number of years in the period chosen. The quotient will be the annual cost of the pavement.

In the absence of reliable data for making an accurate statement of this kind we can make only approximate estimates based on assumed facts, and the result arrived at as to the cost per square yard per year will of course vary with the facts so assumed. I believe it safe to say, however, that an asphalt pavement can be constructed and maintained in first-class order, and renewed when necessary, at a smaller cost per square yard per year than can a pavement of granite block or brick.

In conclusion I would earnestly suggest to city engineers the great importance of collecting and recording all the facts of engineering interest relating to street pavements, since in this way only can we hope to arrive at just and fair conclusions as to which of the many pavements before the public is best and most economical under given conditions. The data urgently needed for this purpose are: first, the cost of construction; second, statistics of travel in tons per square foot, which

should be collected by means of a uniform system, so that the results on different streets and in different cities may be comparable with each other; third, the cost of maintenance; fourth, the life of the pavement; and, fifth, the cost of renewal of the pavement when renewal becomes necessary.

DISCUSSION.

Mr. I. E. Howe.—The first paving laid in Minneapolis was the granite block paving laid on Washington Avenue South, between 3d and 8th Avenues, during the summer of 1882. The granite blocks were laid in three inches of sand, with sand-filled joints and gravel top-dressing.

At the time when the paving was laid it was a question whether that was the proper kind of paving to lay on such a street, for the avenue runs over what was once a duck pond. But now, at the end of the twelfth year of its use, I cannot think that there was any mistake made.

The expense of repairs made since the paving was laid would not amount to one cent per square yard, and it is a question whether even this small expense would have been necessary in all cases had not the paving been torn up for the different improvements that have been made. The blocks are much smaller than those now generally used. The corners are somewhat worn, so that it is rougher than when it was first laid. Otherwise it is in fair condition.

The same year (1882) the cedar paving on Washington Avenue, between 3d Avenue South and 2d Avenue North, was laid. The blocks were seven inches long and were set on two-inch planks. The interstices were filled with gravel, and flooded with coal-tar paving composition, and a top-dressing of gravel and coal-tar composition was applied.

In making repairs during this last year we have found that some of the blocks are worn down to three inches in length. This, however, is only in the center of the street and at intersections. The planks are still in relatively good condition. This paving is rough and uncomfortable and must be renewed within a year.

The next year (1883) Nicollet and Hennepin Avenues and other down-town streets were paved. We now have 71.6 miles of cedar paving, 9.5 miles of granite and 2.77 miles of asphalt.

When a hole appears in a cedar block pavement it is generally assumed that the foundation and plank have given way, but this is not the case. As a rule, the failure begins with the decay of one defective block. Its neighbors then work loose and a rut or hole may thus be quickly formed, although the planking and foundation are still intact.

The blocks in the center of the street may be worn down to, say, two inches in depth, while those on the side are scarcely worn at all, but the bottoms of the latter, and the planks under them, are attacked by dry rot, beginning at the ends of the cross-walks next to the sidewalk.

In 1887 the first cedar paving was laid in the city without the tar composition, and the depth of the blocks was reduced from seven to six inches. Up to that time it had been the custom to use from 1½ to 2 gallons of the tar composition, using the coal-tar as it came from the gas works and adding enough pitch to make it of the proper consistency. About that time the gas companies all over the country commenced to make water gas, and the price of tar increased until the city thought the benefits derived from it did not warrant its use. I would like to see it resumed, if the city could be sure of getting good refined coal-tar; but crude coal-tar, as it comes from the gas works, is worse than nothing.

Planks saturated with crude coal-tar become completely worthless in two years.

When the Franklin Avenue bridge was built, it was paved with cedar blocks. It was the intention to use paving composition, but very cold weather came on and the composition could not be kept hot long enough. However, about twenty feet of the bridge paving was covered with the composition, using refined tar.

Last year it was discovered that the pressure on the wheel-guard of the bridge, caused by the swelling of the blocks, had cut all the rivets that held it in place. In order to repair it and to get it back into place, a strip of blocks of the entire length of the bridge was taken up, and it was discovered that the flooring and paving were badly rotted except where the paving composition had been used. There the planks and blocks were almost as good as new. I believe that the composition would not only preserve the blocks, but would prevent them from swelling and causing much damage. Paving composition was used on all the bridges paved or repaved last year by the city.

TABLE SHOWING COST OF PAVING IN MINNEAPOLIS, MINN.

Year.	Price per Square Yard. Cedar.	Price per Square Yard. Granite.
1882	$2 07 (with tar).	$2 75
1883	1 57 "	2 72
1884	1 71 "	2 59
1885	1 34 "	2 47
1886	1 16 "	2 14
1887	96	1 80
1888	1 08	
1889	1 00	
1890	95	
1891	85	1 67
1892	84	1 67
1893	85½ with rolling.	
1894	76 "	1 58

At this rate of decrease in price, we should be getting cedar for nothing in eight years, and granite in seventeen years.

The following table of cost of repairs of cedar block paving includes only those repairs rendered necessary by the defects or the wear of the pavement itself, not those chargeable to opening of the pavement for pipe-laying, etc.

COST OF REPAIRING CEDAR BLOCK PAVEMENT.

Year.	Square Yards Paved.	Cost of Repairs for 1893. Labor.	Material.	Total.	Total Cost per Square Yard.
1882	14,734	$75 12	$23 85	$98 97	.00671
1883	21,940	23 00	9 10	32 10	.00146
		* 6 00	* 2 80	* 8 80	
1884	65,767	144 75	63 90	208 65	.00317
1885	37,377	81 45	26 28	107 73	.00288
1886	27,703	65 95	20 10	86 05	.00310
		*31 00	* 8 40	* 39 40	
1887	121,158	59 83	19 35	79 18	.00065
1888	127,352	6 00	. . .	6 00	.0000047
		*11 00	* 6 00	* 17 00	
1889	81,141	64 75	24 85	89 50	.00110
		*84 00	*36 40	*120 40	
1890	130,392	65 75	20 30	86 05	.00066
		*10 00	* 4 00	* 14 00	
1891	166,549	27 50	10 13	37 63	.00022
		*65 00	*20 80	* 85 80	
1892	87,351	2 00	. . .	2 00	.000002
1893	84,878	3 18	. . .	3 18	.000003
Total	966,342	. . .	. .	837 04	.00076
				*285 40	
				$1,122 44	.00115

* Caused by floods.

As to the question of the amount chargeable for making openings in pavements, it should be observed that the mere cost of relaying does not cover the damage to the roadway, which is never as good after relaying as before.

In Chicago and in St. Paul I have seen places where the cedar blocks are completely worn away, the traffic coming directly into contact with the underlying planking. In Minneapolis we do not allow our pavements to get into such condition.

Except as to noise, our granite pavements are giving good satisfaction; but I should prefer the use of smaller blocks, and they should be brought more carefully to a true surface.

It has been questioned whether asphalt paving would stand the sudden changes of temperature to which our city is subject. These sometimes amount to 70° within twenty-four hours.

The only asphalt pavement in Minneapolis is that on Park Avenue. For want of proper facilities this has not been kept properly cleaned, but its cleaning would involve only a small expense.

THE CORROSION OF IRON PIPES BY THE ACTION OF ELECTRIC RAILWAY CURRENTS.

By Prof. Dugald C. Jackson.

[Read July 11, 1894, before the Western Society of Engineers.]

The foundation of this paper is an investigation carried out under my direction by Paul Biefield and Fred D. Silber at the University of Wisconsin. I have incorporated the report of their experiments directly into the paper as far as possible. Their work was divided under two heads: First, to determine what chemical action really occurs under the conditions that are met in towns where corrosion of the water and gas pipe systems has been caused by the action of electric railway return currents; second, to examine the action which has actually occurred in various towns, to apply the deductions gathered from the results of the first division of the work, and to determine the best methods of avoiding difficulty or danger from corrosion.

About two years ago engineers of the West End Street Railway Company of Boston began to connect the reinforcing wire, laid between the tracks, to the water pipes, anticipating little or no trouble from so doing. They soon found that the supplementary wire was destroyed in places. They first attributed this to chemical action of the soil, but finally concluded that it was due to electrolytic action. As a remedy, they reversed the polarity of their generators, sending the current out through the rails and back through the overhead trolley wire. This change was followed by disastrous results. The current pumped through the rails, took to the water pipes and to the lead cable coverings, following the law of divided circuits, and, leaving these at many points along the line, caused serious corrosion at these places. It was found that at some points lead pipes disappeared within six or eight weeks and that galvanized iron and brass pipes deteriorated noticeably in an equal time.

After a conference between representatives of the city and of the railway company, it was decided to return to the old method of current distribution. The direction of the current was therefore again reversed, and careful tests were made, which showed that a considerable current flowed along the water pipes. So great in fact was this current that the arc formed at a joint where oakum was used for calking was sufficient to set fire to the oakum. The loss of pressure on the return circuit was found to be from 25 to 100 volts, or from 5 per cent. to 20 per cent. of the total pressure. As an experiment, the water system was connected with the negative pole of the dynamo, and a new danger was now

found in the difference of potential between the gas and the water pipes, causing a marked electrolytic effect on the former. It was then proposed to connect the gas and the water pipes together in all parts of the city in order to arrest the action, and this was done, with fair results; but the expense to the city and to the company was great, and the final solution of the difficulty was far from satisfactory to either party.

The report of the Board of Commissioners of Electric Subways of Brooklyn for 1892 briefly referred to the same trouble as of uncertain character and extent. Since then the problem has become very serious in Brooklyn on account of the growth of the electric railways in that city, and the report for 1893 calls attention to the fact that discoveries of corrosion have been numerous enough to justify the belief that all kinds of buried pipes are being eaten away in many places. As an example may be cited the fact that a certain iron service pipe buried at a depth of four feet below the track had been completely perforated in a month. In Brooklyn, as in Boston, connection between the return circuit and the corroded service has been tried with some success. In Brooklyn the matter is as yet in an experimental stage, so that proposed extensions of the railway system along the line of one of the largest water mains in the city is regarded with anxiety.

Milwaukee also has had her share of trouble from the same cause. O. M. Rau, electrical engineer of the Milwaukee Street Railway Company, tells about it in an article in the *Street Railway Review*, in December, 1893. At two hundred feet from the power house on Wells Street a six-inch water main was so badly corroded, after the electric railway had been operating for four years, as to render it entirely useless. When taken out of the ground it was so soft in places that a cane could easily be poked through it. In Milwaukee the corrosion was arrested by making numerous low-resistance connections between the pipes and the rails, thus keeping the two at the same potential. The connection is made most secure at the power station, where both pipes and rails are led to the negative pole of the generator by heavy cables. It is found that as much as 28 per cent. of the total output is now returned by means of the pipes, and no difficulty is encountered. The plan has been working very satisfactorily for over a year.

The Chicago experiences have been set forth in a report made by Prof. Barrett to Mayor Harrison in June, 1893. The destructive effects in Chicago seem to be entirely similar to those of the cities above mentioned. Prof. Barrett's report mentions some experimental work in which a current of 0.3 ampere, continued for three weeks, was most destructive to a lead telephone cable, while a cable which was buried in the same soil, but was not subjected to the action of the current, was unaffected.

In Zanesville, O., a four-inch cast-iron water main was completely perforated in two years. All the neighboring pipes were affected, some of them lasting only six months.

Columbus, O., Hamilton, Ont., Indianapolis, Ind., Philadelphia, Los Angeles, Cal., and many other cities where considerable electric railway systems are in operation, have experienced the same difficulties. In every case the corrosion has exhibited the same general features and has pointed to the same cause.

It is now practically agreed that the reason for the extraordinary corrosion is to be found in the imperfect character of the return circuit of electric railways. When such railways were first constructed, the rails, in connection with the surrounding earth, were relied upon to carry all the current back to the generator. It was soon discovered, however, that the current would not confine itself to this path and that the resistance of the earth was far from being as low as was originally supposed. Bonding the rails, cross-bonding, supplementary wires and ground plates were then tried. The last were found to be of but little avail, while the copper bonds and supplementary wires were often themselves electrolyzed, and bond wires have frequently been far too small in cross-section for the large current to be carried. The tendency which now properly obtains is to make the return circuit of fully as great conductivity as that of the overhead supply circuit, without relying upon any conductivity from the ground. This is being accomplished by perfecting the rail-bonds and running heavy track feeders, or by electrically welding the rails. There is little doubt that with a perfect return system, which is properly connected to systems of underground pipes, electrolytic disturbances will practically disappear in nearly all cities.

Although the corrosive action of the return current has been so frequently noticed and commented upon, no one has really determined what actually occurs in the ground under the conditions brought about by the operation of electric railway systems. Two theories have been put forward relative to the corrosion: First, that it is simply due to chemical action caused by ammonia, saltpeter, leakage from gas mains, etc., found in the earth; second, that it is the result of electrolytic action. While simple chemical action undoubtedly has much to do with shortening the life of a pipe, it evidently cannot produce effects of the magnitude of those noted above. The ordinary life of water and gas pipes, where chemical action alone is met, is said to be about twenty years, while the corrosive action with which we are dealing has destroyed new pipes in intervals of from a few weeks to half a dozen years. In every case of the corrosion to which we refer, an electric current has traveled along the pipe, and the corrosive action has taken place at the point where the current left the pipe. This is conclusive proof of elec-

trolytic action. Secondary chemical reactions play an important part in the final decomposition of the pipe, and these are dependent upon the character of the salts in the soil, but the current sets the ball rolling. The electrolytic action of the current may occur in either one of two ways—(1) by direct electrolysis of iron and (2) by electrolysis of chemical compounds which are held in the water of the soil, which results in secondary chemical reactions at the electrodes. In order that electrolysis may occur, it is necessary to have the equivalent of an electrolytic cell. In the case of a current leaving a pipe at any point, the pipe is the anode or positive plate of such a cell, the water of the soil, containing the chemical compounds in solution, is the electrolyte, and the rail is the cathode or negative pole of the cell. All corroded iron pipes taken from the earth present practically the same appearance. They are generally "pitted" in many places, and, although the pipe is covered with a layer of reddish oxide, the bulk of the corroded metal has generally been entirely carried away, presumably by a secondary chemical change.

In order that the first electrolytic action (that is, direct electrolysis of iron) may proceed, a soluble iron salt must be present in the soil, reaching from anode to cathode. The analysis of street soils shows no such salts, and hence we are safe in concluding that this factor does not enter into the corrosion to any practical extent. The point has been made by several writers on the subject that the phenomenon may be due to the electrolysis of water, the nascent oxygen set free at the anode attacking the iron directly, and forming iron oxide. An examination of the facts of electrolytic action shows that this effect is not of practical magnitude. This leaves us but one hypothesis to work upon—that is, the electrolysis of substances held in solution in the water of the soils, with a resulting secondary chemical action on the pipes.

In order to determine as exactly as possible the results of the action of the return current in the soil, a series of laboratory experiments were performed, in which the practical conditions were reproduced as fully as possible.

Almost every chemical analysis of street soils shows the presence of some soluble salts of ammonia, potash and soda, and an experiment was therefore made to determine the effect of these salts on the electrolytic corrosion of iron plates per ampere hour. Six small electrolytic cells were run in series under an electric pressure of about 100 volts, with a current varying from 0.2 to 0.04 ampere. The cells contained clean glass sand moistened with water containing the salts.

Cell No. 1 contained $NH_4\ NO_3$. (Nitrate of ammonia.)
" " 2 " $NH_4\ Cl$. (Chloride of ammonium.)
" " 3 " KNO_3. (Nitrate of potash.)

Cell No. 4 contained KCl. (Chloride of potassium.)
" " 5 " $NaNO_3$. (Nitrate of soda.)
" " 6 " NaCl. (Chloride of sodium.)

After a run of 14¼ hours the number of ampere hours was 0.7465.

Loss of anode of NH_4NO_3 cell per amp. hr. was 0.921 gramme.
" " " " NH_4Cl " " " " 1.314 grammes.
" " " " KNO_3 " " " " 0.887 "
" " " " KCl " " " " 1.346 "
" " " " $NaNO_3$ " " " " 0.729 gramme.
" " " " NaCl " " " " 1.299 grammes.

Previous experiments upon cells containing these salts had shown that iron was carried off from the positive plates, but was not deposited on the negative plates. The deposit of iron was made in the form of a layer of hydrate or hydroxide of iron near the middle of the cell. The same was true of experiments made with cells containing street soil where only a comparatively small percentage of carbonates was present. This explains the remark, often made in reports on the corrosion of pipes, that the products of the corrosion had disappeared. It was noticed during the experiments that all the cells containing a nitrate gave off a gas at the anode, and this, on being collected, was found to be oxygen. The same cells showed an acid reaction at the anode when tested with methyl-orange, and the reaction diminished in intensity as the current decreased. In cell No. 1 of the series already referred to, this acidity failed to show itself when the current fell to 0.6 ampere; in cell No. 3 at 0.045 ampere, and in cell No. 5 it was very faint at 0.04 ampere when the current was shut off. The acid reaction and the escape of oxygen in these cells seemed to be associated, and here it becomes necessary to refer to the losses of the anodes in the different cells. It will be seen that the chloride cells exhibit the greater losses, while the nitrate cells show the smaller. Moreover, the cell containing a nitrate in which the formation of acid and of oxygen first came to a stop, shows the greatest anode loss, and one in which it continued to a slight degree to the end of the experiment shows the least. These facts point very strongly to the soundness of the theory which has been finally worked out; namely, that in an electrolytic cell with iron electrodes and a soluble salt or salts of the metals of the alkalies or alkaline earths in solution in the electrolyte, the salt is electrolyzed by the current, and the acid radical attacks the anode, forming an iron salt, while the alkaline metal forms with water a hydroxide at the cathode, liberating hydrogen there. Finally, the meeting by diffusion of these two products precipitates ferrous hydroxide (FeOH). As the amount of electrolysis varies with the strength of the current, a comparatively high current will liberate the acid radical more rapidly than it can combine

with the iron, the critical point depending upon the affinity of the acid radical for iron. When this excess is produced, the radical forms an acid by combining with water, and at the same time liberates oxygen. Neither the acid nor the oxygen can combine with the anode, because that is already engaged in the formation of an iron salt with the acid radical, and hence the gas escapes into the air. If the acid is formed in sufficient quantity, it diffuses itself through the electrolyte, meets the alkaline hydroxide and forms the original salt and water. In the case of chlorides, the nascent chlorine liberated at the anode, forms with it a chloride of iron, and, if the current is strong enough to form an excess of chlorine, it will be dissolved in the water, and may, under the influence of light and heat, form an acid and liberate oxygen; or, if enough heat is generated, free chlorine will be given off, as is shown by experiment. All the conditions of these laboratory experiments are practically paralleled in the earth, and hence it is safe to say that similar chemical reactions must go on there. Although the composition of street soils is more complex than that of the electrolytes used in these experiments, they nevertheless contain the same soluble salts, and, as these are diffused through the moist earth, they must lend themselves to exactly similar electrolytic influences and chemical changes. In fact where street soils were used in the experiments as the electrolytes of cells which were placed in series with cells containing known quantities of simple and mixed soluble salts, the losses of the anodes were entirely comparable. It is thus seen that only such measures as will stop the electrolytic action of salts in solution in the soil can be relied upon to stop the corrosion of iron pipes.

The soil frequently contains carbonates of lime and magnesia, which are dissolved by carbonic acid in the water. When carbonates are present in the water to a considerable degree, a reddish layer of iron carbonate is found on the pipe. This is generally mistaken by observers for oxide of iron, but we have never found the latter present as a result of electrolytic corrosion. To find the effects of carbonates upon the corrosive powers of soils we ran four electric cells in series. The first two had for electrolytes glass sand moistened with a $\frac{1}{2}$ per cent. solution of chloride of sodium in distilled water, and the other two had the same electrolite with the addition of a solution of carbonate of magnesia and carbonate of lime of uncertain strength. The latter solution was obtained by passing carbonic acid for $1\frac{1}{2}$ hours through water containing equal parts of these carbonates in suspension. The test current was kept at 0.09 ampere for 7 hours, making 0.63 ampere hour.

The average loss of the anodes of the cells containing chloride of sodium alone was 0.6565 gramme, while that of the carbonate cells was 0.601 gramme. This makes it evident that the presence of the carbon-

ates does not aid in the corrosion of the anode, and even the slight cathode loss, due probably to ordinary oxidation, is less in these cells than in those containing the chloride only. The difference in the losses of the anode is easily explained. In some previous experiments the losses of anode caused by the electrolysis of a nitrate, of a chloride, and of a mixture of the two, were compared. The chloride caused the greatest loss of anode, the nitrate the least, and the mixture caused a loss between the two. In the same way, in the case of the carbonate and the chloride, the chloride caused a certain loss of anode, and when the chloride is mixed with carbonate the loss is somewhat less than when the electrolyte is a chloride alone. The fundamental effect of the carbonates is shown by a further description of the experiment. Soon after the current was turned on, the chloride cells began to show the formation, between the electrodes, of the ferrous hydroxide layer already mentioned, while the other two cells showed a reddish layer formed at the anode, spreading toward the cathode as the action progressed. The reddish layer consisted of carbonate of iron, which was formed by the action of the carbonates upon the products of the electrolysis.

The results of many experiments, and the condition of corroded water pipes as observed, leads to the conclusion that under the conditions existing in street soils the corrosion will primarily go on by virtue of the acid radicals of the hydrochloric, nitric, sulphuric and other acids, the carbonates held in solution by virtue of the carbonic acid acting merely to change the ferrous salts to the normal iron carbonates, and the ferric salts to the ferric hydroxide. Should the carbonates in solution be electrolyzed in addition to the salts of the alkaline metals, the carbonic acid radical would not attack the iron, as the corrosive power of the other acids is so much greater, but would again form with the ferrous salts the iron carbonates.

Owing to the doubt which exists as to what is the minimum voltage required to cause electrolysis of water pipes by the railway current, a series of determinations was made by means of the electrolytic cells. The iron electrodes were inserted in clean glass sand 1.5 centimeters apart, and had about 20 square centimeters exposed area. In the first cell a 1 per cent. solution of nitrate of soda was used with a voltage of 0.2. As before, the hydroxide layer was formed. The electrolytic action was evident without any special tests. In the following cells the existence of action was shown by chemical tests for the iron salt and the alkaline hydroxide. In the second experiment, a $\frac{1}{5}$ per cent. solution of nitrate of soda was used with 5 volts. The action was at once apparent.

Cell No. 3.	Pressure .25 volt.			Action in 3 min.
" " 4.	" .125 "	1-6 per ct. sol.		" " 5 "
" " 5.	" .100 "	" " "		" " 5 "
" " 6.	" .05 "	" " "		" " 40 "
" " 7.	" .013 "	" " "		" " 50 "
" " 8.	" .005 "	" " "		" " 1 hour.

In cell No. 8 the hydroxide layer began to appear after one hour.

Cell No. 9. Pressure .001 volt 1-6 per cent. solution. Action in 1 hour.
" " 10. " .01 " " in 4 hours 45 min.

In cell No. 10, the electrodes were 20 mm. apart and were 40 mm. by 68 mm. in exposed surface. The electrolyte was street soil.

A suprisingly low voltage produced an appreciable electrolysis in the sand cells. The pressure on cell No. 10 might undoubtedly also have been reduced to a millivolt without stopping the corrosion, but the resistance of the soil was so high and the percentage of soluble salts so low, that the time necessary to produce action would have been considerable. A milliammeter showed a barely perceptible reading in the case of the experiments in which very low pressure was used. The observations plainly show that a mere directive force is necessary to produce electrolysis, and that corrosion is simply a question of current.

It is impossible to give, in a reasonable space, even a summary of the great number of experiments which were made, but the following conclusions are directly drawn from them:

1. In no case is the action due to the electrolysis of water; where oxygen is liberated at the anode, it does not attack the iron.

2. A mere directive force, in the nature of a pressure, will cause electrolysis.

3. The actual corrosion is, therefore, dependent only upon the actual current, which in turn is as much dependent upon the resistance of the soil as upon the pressure tending to cause the current.

4. A minute quantity of soluble salt is sufficient to start the action, and the action will then continue as long as a current flows.

5. The seriousness of the corrosion of a pipe depends on the amount of current flowing from a given area, and upon the nature of the salts present in the soil, the order of the activity of the salts being (1) chlorides, (2) nitrates, (3) sulphates.

The fifth conclusion is exact only when the density of the current is below the critical point. As already stated, the experiments showed that electrolytic action may be made to proceed more rapidly than the iron can be corroded by the electrolytic products. With the nitrates, this critical density is near 0.01 ampere per square inch, and it is much higher for chlorides. The rate of 0.01 ampere per square inch is not likely to be often exceeded under the conditions of practice, and a current of that density will completely perforate a large iron pipe in a fraction of a year.

The following table gives the average loss of iron from the anode per ampere hour, due to different salts and mixtures of salts. It must be remembered that the cathode or negative pole in no case showed a gain, but generally showed a slight effect due to simple oxidation.

Electrolyte.	Loss per ampere hour.	
Street soil	.8	gramme.
" " from Madison Electric Ry. route	1.16	"
" " " " " " (clay)	1.14	"
" " " in front of Madison power station	.91	"
	1	gramme.
Sand with Na_2SO_4	.66	"
" " KNO_3, ½ per cent. solution	1.03	"
" " NH_4Cl " " "	1.38	"
" " KNO_3 } " " " mixed " " KH_4Cl }	1.084	"
" " NH_4NO_3	.921	"
" " NH_4Cl	1.314	"
" " KNO_3	.887	"
" " KCl	1.346	"
" " $NaNO_3$	.729	"
" " $NaCl$	1.299	"
Average loss of chloride cells	1 335	"
" " " nitrate cells	.892	"
" " " sulphate cells	.660	"

One ounce is equal to about 28⅓ grammes.

The averages emphasize the fact that the chlorides produce the greatest losses of metal, nitrates coming next, the sulphates last, the mixtures in an intermediate place. This seems to show that the corrosive power of the acid radical varies in general as the activity of the corresponding acids.

In Mr. I. H. Farnham's paper on "The Destructive Effects of Electrical Currents on Subterranean Metal Pipes," which appeared in the *Transactions of the American Institute of Electrical Engineers* in April, 1894, the statement was made that when the current was reversed every minute during a period of ten days, no material change took place in either plate during that time. Our experiments have shown that only the positive plate or anode is affected by the electrolytic action, which occurs under practical conditions, and hence we should expect that, when the current is frequently reversed, both plates will be corroded, since they are alternately positive, unless the frequency of reversal is too rapid for chemical action to occur at all. In order to ascertain the effect of such reversals, the following experiments were performed with an electrolytic cell containing a weak solution of nitrate of soda. The period of reversals ranged from fifteen seconds to five minutes, the current being 0.04 ampere under a pressure of two volts. After a few

of the quarter-minute reversals, the presence of the iron salt was detected at both plates by potassium ferricyanide tests. On prolonging the periods the iron reaction diminished at one plate and increased at the other during one period, and *vice versa* in the following period. When the period of reversal reached 2½ minutes, the electrolytic effect was very evident; the iron salt disappeared at one of the plates with each reversal, giving way to alkalinity. The experiment showed that the minimum period of reversal during which corrosion occurs, must be less than fifteen seconds, and this fact of itself makes the prevention of corrosion by reversals entirely impracticable.

The problem of preventing the destructive electrolysis of iron pipes by the railway return current is shown to consist simply of the prevention of electrolysis of the salts in the soil when the products of electrolysis are of such nature as to attack iron. It is a problem that requires a careful study of the local conditions in each case before it can be satisfactorily solved. I am quite confident, however, after carefully studying many cases of corrosion and applying the conclusions of these experiments, that there are very few places where the difficulty cannot be avoided by proper construction and arrangement of return circuits. This can ordinarily be done at a comparatively small expense, and with a resulting advantage to the operation of the railway. Among the conditions that exert the most marked influence upon the corrosion are the nature and amount of the soluble salts in the earth, the resistance of the earth itself in the locality, and the difference of electrical pressure between the pipes and the rails or other conductors. High differences of pressure do not necessarily imply a high degree of action, as is shown by the condition of the Madison water pipes. Here, as much as seven volts is found between the rails and the pipes in front of the power station, and yet only a very small amount of corrosion is shown after 1½ years' time. Evidently the resistance of the path here must be very high or the quantity of soluble nitrates, chlorides or sulphates is extremely small. The fact that a special and ingenious instrument, made to measure the amount of current, showed but 0.0C03 ampere, leads to the former conclusion. On the other hand, with the favorable conditions of a low resistance path between the pipes and the rails, and a relatively large amount of soluble salts in the earth, there is no doubt that serious electrolytic effects may be produced where a quite small difference in pressure exists between the pipe and the rails. The extent of the railway system does not always offer a guide to the destructive influences of the return current. Mr. Farnham, in his paper previously referred to, mentions a small road in Rockland, Me., where much damage was done to pipes in five months, while the system in Madison, which is probably fully as large, shows up to date (a period of nearly two years) a barely appreciable action.

Alternating currents produce no appreciable electrolysis, and their employment would avoid all difficulty, but their use for driving street railway motors is not yet an assured success.

The use of a double trolley system of conductors would also avoid the major portion of the difficulty, but I believe it can be equally well avoided by proper construction where the usual single trolley systems are used. This question has no real bearing upon the discussion of single versus double trolley systems. If single trolley systems were really well built, less talk of double trolley systems would be heard. One great advantage of double trolley construction lies in the absolute certainty of its failure if the insulation of the lines is not excellent.

Connecting the pipes with the rails by means of heavy cables, at points where the former are positive to the latter, proves to be the most complete method of prevention. The conductivity of the track circuit must be properly reinforced by feeders, so that an undue drop is not experienced in the return conductors. These track feeders should always be insulated, and put on the lines exactly as are overhead feeders, in order to save them from corrosion. The connection of pipes and rails has been practically carried out in Milwaukee, Wis., at a cost of about $8,000, and has apparently done away with the trouble, at the same time decreasing the resistance of the return circuit. In the Milwaukee system there are about 125 miles of track, with over 200 cars in daily operation. The track circuit was originally put down in excellent shape. In the Madison system present indications show that one connection between rails and pipe system opposite the power house, costing all told about $15, would prevent any serious action. Investigations have shown that when the negative pole of the generator is connected with the trolley, the pipes are positive to the rails over an extended outlying district, and corrosion goes on over a large area, while with the reversed arrangement the dangerous area is concentrated about the power station. The latter method of connection allows the difficulty to be most easily handled, and, after the district within which the pipes are positive to the rails has been accurately determined by proper voltmeter tests, frequent connections of pipes and rails should be made within its limits. This can usually be done at a comparatively small cost, the interest on which may be annually saved by the decrease of lost power, if the connections are properly placed. The boundaries of this district should be re-checked from time to time, and such changes in connections should be made as the tests show to be necessary. The outlines of the "danger district" are likely to vary with the growth of the system, and even to change slightly with the seasons, and the connecting wires may be eaten away; so that eternal vigilance is here, as everywhere, the price of safety, but safety may be absolutely secured in most cases.

Proper tests with a satisfactorily arranged voltmeter, such as was used in testing the Madison road, seem to give sufficient indications of the density of the current leaving the pipes at any exposed point. Such tests, when reinforced by chemical examination of the soil, may probably be used with advantage in determining the extent of the corrosive action occurring at any point.

I have not touched upon any argument in regard to the really serious corrosion which has sometimes occurred from other causes than electric railway return circuits. This is a matter which is now generally understood, but is of less magnitude in most cases than the electric corrosion. The owners of pipes are often at fault in having filled the soil with electrolyzable salts, but even in that case they may generally avoid danger by proper co-operation with the railway companies.

DISCUSSION.

Mr. O. M. Rau.—In Milwaukee we had a case which leads me to believe that the condition of the soil is as much responsible for the corrosion as is the electric current. On a railway line built about four years ago, a No. 4 copper wire was laid as a supplementary track feeder. On investigating recently the condition of this wire it was found to be entirely eaten away on the lower end of the line, while on the upper end it was in as good a condition as when new. The electric conditions were the same throughout the entire line, as the power house is situated in the center of the circuit. This instance, as well as others, indicates that the leakage of electric current will not noticeably affect a pipe unless the chemical nature of the soil is favorable to this action. In a number of places, where the water pipes were affected, special care was taken as to the kind of filling used, lake sand or gravel being considered best.

Mr. A. V. Abbott.—Professor Jackson's paper is an exceedingly valuable contribution to engineering literature. The author has accurately determined the amount of corrosion per ampere hour, or per unit of electrical energy expended, thus obtaining data from which we will be able to calculate the probable effect of the corrosive action. He has also demonstrated what is still more important, namely, the amount of electrical pressure required, not only to initiate the trouble but to constantly maintain the action. These experiments are in line with those made by Mr. Farnham, who showed, in one experiment, that a piece of lead wire about three inches long and nearly $\frac{1}{16}$ inch in diameter, was dissolved in pure hydrant water; that is to say, in water as pure as is obtained from the Boston Water Works. The lead was entirely dissolved,

with an electrical pressure of $\frac{1}{100}$ of a volt, in about a week's time. This is not only confirmatory of Professor Jackson's investigations, but, furthermore, points to the conclusion that very small quantities of the electrolytic salts, to which Professor Jackson has called attention, are sufficient to initiate and to carry on corrosive action. The actual amount of lead which passed into solution was not very great, but all examinations as to the injury done to underground structures, have shown that the difficulty arises from an extensive pitting of the metallic surface ; a single hole will incapacitate a 30-inch water main as seriously as if the whole pipe were dissolved.

The amount and the rapidity of the corrosive action seem to vary greatly in different localities, and under different circumstances. The first action was noticed in Boston, in the summer of 1891, three years or more after the first installation of the electrical system of the West End Railway Company. Injury was first discovered by the telephone company in Boston, in the effect upon the leaden sheaths of their underground cables. The Boston reports indicate that some of the smaller service pipes, both of the water and of the gas systems, have been injured, but no damage is reported to have occurred to the large mains, although the engineers of the West End Railway have expressed the opinion that there is a probability of the existence of extensive corrosion. In the Brooklyn experience, however, within a very few months after the substitution of electrical propulsion for animal traction, extensive injury to the largest gas and water mains in the city was noticed, injury which, in Court Street, necessitated the replacement of several lengths of large gas main.

Professor Jackson has shown very clearly that a pressure of 0.001 volt (an electrical potential requiring for its detection the most delicate of instruments) is sufficient to cause injury, if its action is allowed to continue. Should all electrical industries be allowed to pour their energy indiscriminately into the earth, it would be only a short time until such small differences of potential as this, would be found all over the areas covered by our towns and cities. It is, therefore, merely a question of time, when underground structures will be seriously menaced and rapidly destroyed by currents of this kind.

Some years ago I had the good fortune to construct about three hundred miles of electric railway, and at present I represent the engineering department of the Chicago Telephone Company, and I have thus been on both sides of the fence, and have had fair opportunities to see and to consider both sides of the question. In my earlier electrical railway experience, the double trolley was still in vogue, and I constructed several roads of this kind I have always advocated the idea that each individual electrical company, no matter what its business

may be, ought to have its own complete, entire and private circuit. The idea of constructing arc-light plants, incandescent-lighting stations, telephone and telegraph circuits, and electrical railway lines, with the probability of an indefinite extension of electrical circuits in the future, and to dump the entire energy, from all such sources, into a common tub, is absurd. In any other branch of engineering, such mutual interference would not be tolerated for a moment. Already every electric lighting company is required by law to provide its own independent and private circuit. Nearly all the telephone companies are rapidly changing their lines from grounded circuits to metallic circuits, not only on account of the injury to which they are subjected from the other electrical companies, but also because experience has shown that the service obtained by the use of the individual circuit is attended by far better results. By this means each company secures a private right of way peculiar to itself, which not only does not interfere with other circuits, but is not interfered with by them.

Professor Jackson has shown that either by the construction of a double trolley road, or by providing an electrical road with a sufficiently adequate return circuit, the question of injury to underground structures, no matter what they may be, is completely and satisfactorily solved. This is also the remedy proposed by Mr. Farnham.

In Chicago, little or no trouble has as yet been experienced with underground structures, because the trolley roads are now only in the outlying parts of the city, where a few metallic underground structures exist, and where the earth is in good condition to form a return circuit. Only a few trolley roads have at present been placed in operation, and these have been operated only for a short time. The electrical road, however, is bound to extend, and doubtless, in some form or other, will penetrate to the heart of the city before many years elapse. Some of the Chicago elevated roads are already taking up the problem, and preparing to change their equipment to one furnishing electrical propulsion. Unless they provide themselves with individual circuits and build those circuits in such a way that underground structures will not form a path for the current, trouble will, sooner or later, occur.

Investigations in Brooklyn and in other cities have shown that in some cases the current followed a gas or water main, skipping along the main from point to point, running from the main into the earth, and from earth back into the main, depending upon the resistances of the joints. Thus many points of corrosive action were initiated, resulting in widespread and extensive injury to the pipes. Such occurrences will be more and more frequent, as trolley roads increase in number and in extent, and as more current is dumped into the earth.

Mr. Rau has related an experience in Milwaukee, where the diffi-

culty was overcome by excavating around the water mains in the return electric circuit, and introducing clean gravel, or sand. For a very limited district, such an expedient may be a success, but it would be utterly impracticable to equip a large city upon this plan. Neither does it seem possible that such an expedient would be a final remedy for the difficulty. The constant accumulation of organic salts in the street, from animal refuse, would sooner or later impregnate the cleanest and freshest soil with a sufficient quantity of decomposable organic acids to initiate corrosive action. It appears to me then, that the remedy lies with the engineering societies, which should formulate such specifications and restrictions, applicable to various electrical industries, as should on the one hand protect existing structures, and, on the other, encourage the development of electrical enterprises, by securing such an improvement in both the quality and the quantity of the materials and workmanship, as shall obviate the defect of poor and cheap building, so forcibly pointed out by Prof. Jackson.

The advantage of the electric road lies in its economy of construction. The best cable roads cost from $125,000 to $200,000 per mile while a first-class trolley road may be built so as to cost not over $60,000 per mile. The electrical road attracts the capitalist because he can earn more on his investment from it than from any other. The single trolley road offers a special inducement, from the fact that it requires only one-fourth the copper necessary for the double trolley, and consequently requires a proportionately decreased investment for its original installation, but electric railway engineers are finding that this is an expensive economy. In my own experience I have seen a return circuit through rail bonds running so hot that for a space of one thousand feet the bonds have burned their way through the ties, allowing the rails to spread to such an extent as to derail the cars. All energy thus lost in these rail bonds demanded a correspondingly greater expenditure of coal, and to that extent diminished the earnings of the road. An electric railway can be built for $30,000 a mile, but, after construction has been undertaken upon this basis, it has been found impossible for such roads to pay any dividends. In the past, the work has been done, not too economically, but too cheaply. If the capitalist would take the advice usually given by the engineer, if he would plan his entire circuit, both the outgoing and the return branches, in such a manner that not more than from 5 to 8 per cent. of the energy generated by the station is consumed in the circuit, half of the electric roads now in the hands of receivers would be earning and paying good dividends. They already have the necessary business, and the question of dividends depends upon economical operation and maintenance. Assuming an interest and depreciation account of from 10 to 12 per cent., a very little

calculation will show that in nearly every road in this country additional copper in the line circuits will earn a good return on the investment. It therefore seems to me that the true policy is to improve electric railway construction to such an extent as to render not only the best engineering construction, but, in the end, the cheapest for the capitalist, and the least injurious to other enterprises.

Mr. Thomas Appleton.—On the north side, in this city, there is a double trolley line in which both wires are placed in a conduit below the surface of the street. I understand also that this same system is used in Washington, D. C., and that it is successful.

Mr. Shnabel.—I would like to ask what objection the companies have to putting in this return wire.

Mr. Abbott.—It is simply a question of the cost of the copper. The fact of their importance has never been appreciated. The actual cost of the circuit is increased about three-fold. It requires about four times as much power of the same potentiality in the circuit and four times the amount of copper. Of course the labor of insulation is considerably cheaper.

Mr. Shnabel.—How often would that have to be connected with the rail?

Mr. Abbott.—The oftener, the better. In fact, when we come to the double trolley road, they have a continuous connection. In the double trolley you do not depend upon the rail at all. Depending upon the rail succeeds perfectly, so far as distribution of energy to the cars is concerned, but it does not prevent the current from leaving the rail and passing to other metallic structures. The difficulty is due, as Professor Jackson has shown, to the fact that a very small amount of electric pressure is enough to start and to continue the corrosion. If there is a railway extending along a street, and if a thousandth of a volt on a pipe three feet from the rail is going to start corrosion on the pipe, it takes a great deal of copper to protect the pipe. If the railway circuit is independent of the earth, there can be no danger; if there is sufficient metal in the return circuit, other underground structures may be protected.

Mr. Weston.—In the case of an independent return wire carried on a pole the same as a feeder, would rail connections at intervals of from 500 to 1,000 feet afford sufficient protection?

Mr. Abbott.—It is questionable whether 500 or 1,000 feet would not be too great an interval without experiment; I should say it would be well to connect the rail to the return wire at every pole, or say every 100 feet, and the expense of the connection alone would be very small.

Prof. Jackson.—I think that the more frequently connections

are made, especially within the danger district, or in the district in which the action is most severe, the better will be the result.

Mr. Davis.—I infer that you consider it necessary, in all roads that have return circuits through the rail, to connect with the water pipe also.

Prof. Jackson.—This is necessary within the district where the pipes are positive to the rails; that is, where the currents are returning from the pipes to the rails. As long as the current is flowing into the pipes no damage whatever is done, but in any portion of the district served in which the current flows from the pipes to the rails, the greatest care must be exercised. The danger district can be very readily determined by proper measurements carefully carried out, and the connections can be made in such a way as to avoid damage. In a large city, such as Boston or Brooklyn, the currents to be carried are so enormous that the amount of copper required is appalling when looked at in tons or carloads, but, as I said in my paper, the cost of copper is a small matter compared with the total cost of the road.

Mr. Abbott.—Generally speaking, not more than 10 per cent. of the cost of the road; and you double that percentage by preventing any damage that will in future add to the capital charge.

Mr. R. P. Brown.—Do you expect the lake sand around the pipes to do away with the difficulty? After you get the nitrates from the surface, will not the same difficulty arise?

Mr. Rau.—We have carried on most of these experiments in yards and around service pipes which lead from the water mains, so it has generally been in places protected from the foreign substances which are collected from the roadway. Water mains are laid at such depths that I do not think these substances would penetrate to them.

Mr. Brown.—I can see how that might answer for a little while, but it seems to me it would be only a short time.

Prof. Jackson.—In a portion of a district that would be simply a temporary relief.

Mr. Rau.—In most cases this has overcome the trouble to such an extent that where formerly a new pipe was needed every six to eight months we have not had to replace one in two years, and in these places I believe the relief to be quite extended. At any rate, this plan is to be recommended where the drainage is fair.

Prof. Jackson.—In Berlin, where iron-armored cables are laid directly in the earth, they gave good service except under the cab stands, and there the drippings from the standing animals caused the covers of the cables to be eaten away. Clay was puddled around them, and there was no further action, but it is questionable whether there would not be enough salts, even in the clay, to cause electrolytic corrosion.

Mr. Thomas Appleton.—Mr. Abbott, I think, has referred to the danger of the return circuit running down the columns of elevated railroads to the ground. In talking with others on that point, I have maintained that the circumstances were entirely different from those on an ordinary surface railroad ; that in one case the rails are laid in the ground and surrounded by earth, while in the other they are laid on dry wooden ties in no way connected with the earth, and the insulation of the tie would prevent all escape. Hence there would ordinarily be no danger except in case of prolonged rains, when the ties might become water-soaked.

Prof. Jackson.—The rails on the average railway are usually of sufficient capacity for the current due to the traffic. In some of the surface street railway plants in this country, however, the rails which concentrate toward the power station are not sufficient to carry back the current. Having to design the circuit for such a road, I was led to put in track feeders; and I think I was probably the first one to put them in. On elevated railways it will probably be good policy to connect the rails to the iron girders. These iron girders are, of course, electrically connected by means of rivets to the posts, and these stand in the earth. On the other hand the concrete footings of the posts offer a very high resistance, and I think that if the girders are properly connected by bonds, and if the tracks are properly bonded, very little trouble will result from the use of electricity on elevated railroads. It is merely necessary to provide metal of sufficient capacity. The insulation of the tie is, of course, out of account, because the rails are likely to be electrically connected with the iron girders. On the Intramural road at the World's Fair, the girders were placed on wooden posts, but in actual city practice the girders are placed on iron posts.

I believe it would be a mistake to put two overhead wires over each track. I believe the return current can be taken care of underground In large cities we will sooner or later overcome this difficulty by using the double trolley in conduits. But I do not agree with Mr. Abbott that we will ever use the double trolley overhead, except under exceptional conditions. I have made that remark in the light of experience with both types of roads.

Mr. Rau.—When electrolysis occurs it is usually assumed that the return circuit of a road is too small and that the road is too cheaply built, but this is not always the case. The road in Milwaukee has fully three inches in diameter of copper coming into the station for a return circuit, and, although we are overcoming our trouble by connecting the pipes with the rails, I do not think that any amount of copper added to the system would have avoided it.

Putting more copper into the ground is a very expensive method,

and when a loss of $\frac{1}{100}$ volt will affect the pipe, as shown by Prof. Jackson's paper, it requires an enormous amount of copper to prevent so small a loss. I think that if proper connections were made wherever the difference of potential is of such proportion as would cause electrolyric action, the trouble would be entirely overcome with very little expense, and certainly this would be more satisfactory than to rely upon the street railway to increase the return circuit to the required extent.

I am pleased to see that the telephone companies in Milwaukee are accepting the plan by which each company protects its own system, they thus making a series of connections to overcome the difference of potential between their cables and our tracks.

The return feeder is laid in a wooden moulding which is filled with a mixture of pitch and tar. This is pliable and will not get too hard in cold weather, or soft enough to run in warm weather. This practically makes a cheap insulator for the wire, and we find that it preserves the wire very well. After three years' use the wire was found in as good condition as when first laid.

The copper wire is not affected and it should last indefinitely.

COVERED RESERVOIR AT ROCKFORD, ILL.

By Charles C. Stowell, Member of the Western Society of Engineers.

[Read July 11, 1894.]

Rockford is nearly equally divided by Rock River, and as a natural consequence the river was first considered as the source of its water supply.

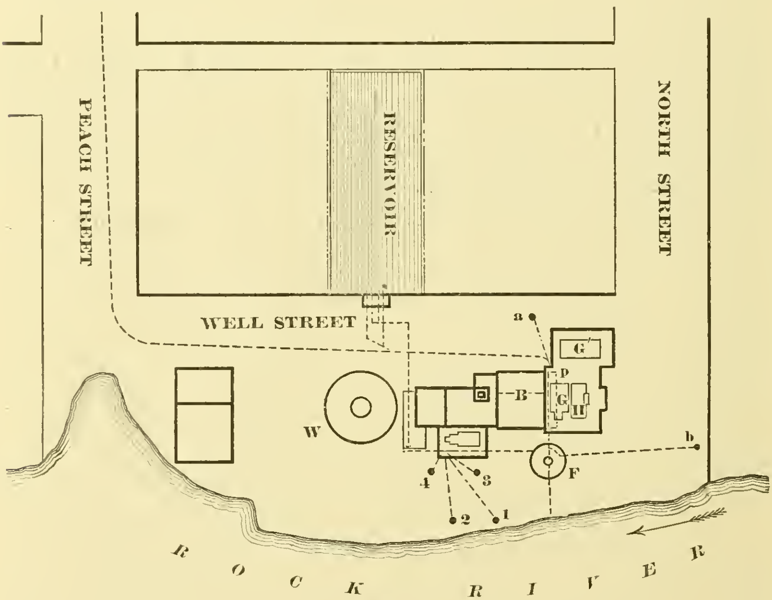


Fig. 1

General Plan of Water Works.

The works are situated on the right river bank, near the center of the city. Between the river and the pumping pit *p*, Fig. 1 (6 feet wide, 40 feet long and 12 feet deep), a filter *F* was placed. This connected with both the river and the pumping pit. A house and boiler room *B* were erected, and a 2,000,000 gallon quadruplex Holly pump *H* and boilers were placed in position.

In a short time the filter became clogged and the river water was admitted directly to the pit. After several attempts to use the filter it was found that it could not be kept clear except at considerable expense, and its use was therefore abandoned.

During the building of the pumping pit much water was encountered, and when the filter proved a failure it was determined to build a large well near the works and to make use of the ground water. A test well of 12 feet diameter was sunk to a depth of about 50 feet below the surface of the ground. This seemed to yield satisfactorily, and a large well *W*, 49 feet in diameter and about 40 feet deep, was accordingly sunk and connected with the filter. This proved inadequate, and also showed that the water was polluted by drainage through the loose sand and gravel through which the well derived its supply.

Five artesian wells, 8 inches in diameter, were then bored into the Potsdam rock. Their depths and locations were as follows:

No. 1, 1,530 feet, at *a*, Fig. 1.
No. 2, 1,320 " on Peach Street, 350 feet from river.
No. 3, 2,000 " " " " 650 " " "
No. 4, 1,300 " at *b*, Fig. 1.
No. 5, 1,379 " on Peach Street, 1,300 feet from river.

No. 1 flowed about 20 feet above the surface when first bored, but lost a portion of this head. Now, with all the wells flowing, it has a head of about 6 feet above the surface. The other wells have nearly the same head as No. 1 now has. A 3,000,000 gallon Gaskill pump *G* was placed beside the Holly, both taking water from the pumping pit. Still later a 6,000,000 Gaskill G^1 was put in, an addition to the building being made for it. Its suction was placed in the same pumping pit. The demand for water soon became general, and the mains were extended. A wholesale waste of water, together with the increase in its legitimate use, began to tax the supply and to leave the higher portions of the city without water during portions of the day, and during the entire day at certain periods of the year.

At this time a water commission was appointed to recommend a system for an increased supply. Mr. J. T. Fanning and our Vice-President, Mr. Mead, were the chief actors. Several systems were discussed, and it was recommended that a storage reservoir be built, also that artesian wells, sunk to the St. Peter's rock, be tried, and if these proved satisfactory that water from them be pumped into the reservoir as a reserve supply. A St. Peter's well was tried (1, Fig. 1), and the water was analyzed and found good. Three other wells (2, 3 and 4) were then bored in the vicinity.

While the last of these was being bored, I was instructed to design a reservoir to be built on a certain lot and to hold from 1,000,000 to 1,250,000 gallons.

The lot was practically 156 by 66 feet, and fronted on the same street as the water works. It was about 210 feet from the river bank. At the front it was about 10 feet above ordinary water level in the river,

and at the back end some 6 feet higher. The bottom of the pumping pit is about 9 feet below the river level.

The ground water, as shown by a well on the lot and by the water in the large well, was at times 5 feet higher than the water in the river.

The elevation of the bottom of the reservoir was first determined, and, owing to the quantity and height of ground water, the floor at the back end was placed at the ordinary elevation of the river water, and the front end 6 inches lower.

The walls were set 2 feet in from the lot line, in order to allow access to the sides should buildings be erected in the adjoining lots.

From these fixed data the height and thickness of the walls were determined.

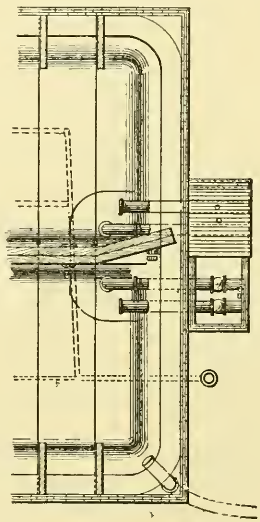


Fig. 2

Plan of Lower End.

Concrete was used in preference to other material, because plenty of sand and stone was at hand for this purpose. The stone was too porous for such masonry as would have been required, and brick was comparatively expensive.

When new wells are bored, considerable sand is thrown out with the water. Hence a double reservoir was desirable, but, as space was limited, only a small portion of the reservoir was taken for this purpose. A longitudinal division wall 2 feet thick and 6 feet high (Figs. 2 to 5) was built through the middle of the reservoir. Two sets of intake and outlet pipes were provided, in order to allow one half the floor to be cleaned while the other half has 6 feet of water above it.

Through the division wall, at the rear end, passes a 16-inch pipe, provided with a valve. Its center is 2 feet above the floor of the reservoir. Ordinarily, the valve in this pipe is left open, so that the water, entering the reservoir by one inlet, can pass through the valve to the other side of the wall. A current is always found to flow through this pipe, even when the water is at its full depth of 18 feet. When one side of the reservoir becomes fouled, the valve in this pipe is closed, and the water in that side is drawn off. The water in the other side can then, of course, stand only at the level of the top of the division wall, or 6 feet above the floor.

In ordinary use, water is let in on one side of the partition and taken out on the other, all the sand being deposited before it reaches the back of the first division.

The outlet and intake pipes were not placed in the bottom of the

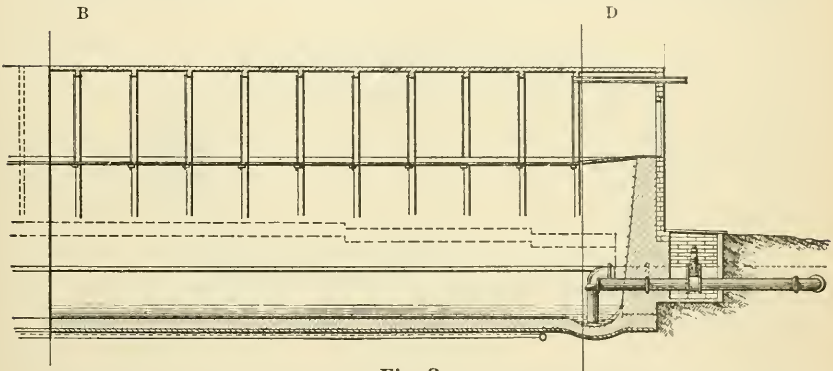


Fig. 3

Longitudinal Section of Lower End.

reservoir, but on a level slightly above the conduit leading from three of the deep wells to the pump pit. This arrangement kept them out of the ground water and allowed a connection with the conduit. The outlet pipes were carried down to within 6 inches of the bottom of the sumps, which were 1 foot lower than the bottom of the floor level; siphonage being depended upon to take the water out from below the flow line of the pipes. The valves of these pipes were placed in a pit under the sidewalk in front of the reservoir.

To protect the concrete walls, to increase their strength above the ground, to form the gables and to improve the general appearance, a brick wall 1 foot thick was built outside, as shown. It rested on concrete brackets cast on the main wall.

The concrete was composed of one part (by measure) of cement, two parts sand, and five parts stone broken to a 2-inch ring.

To determine the relative values of the cements, and to keep a check on that used in the work, a testing machine was constructed, using a pair of steelyards hung in a frame, with clamps adjusted to the frame and steelyards. Samples from each package used in the work were tested both as to free lime and as to tensile strength.

In order to intercept the ground water as much as possible, the work on the walls was begun at the back end, and from here carried around on the sides. The corners were rounded, as shown, in order to give the wall a uniform thickness and to facilitate cleaning. The concrete wall proper was 4 feet 6 inches thick at bottom and 2 feet 6 inches at top. The batter was wholly on the inside. The concrete was placed in 6-inch layers. Under the concrete bottom a layer of clay 4 inches thick was placed just in advance of the work, to prevent the water from washing the cement from the concrete. On the clay a layer of 8 inches of concrete was rammed, and following this a layer of 7 inches

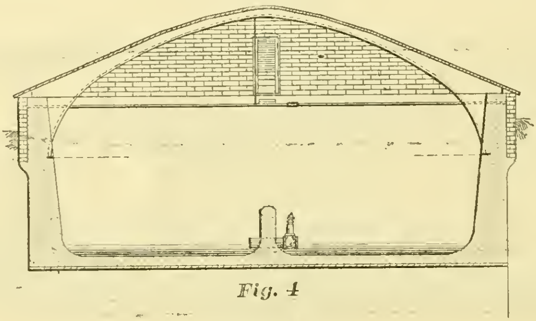


Fig. 4

SECTION A B.

thick, making the total bottom 15 inches thick of concrete and 4 inches of clay. An opening in the upper layer was left for a footing for the division wall.

So much water was encountered, and the porous character of the ground gave it so free a circulation, that it was found necessary to provide for its removal. Accordingly, a sump was dug in one corner of the lot, and a pump was placed in it. Ditches were kept open to it, and, as the first layer of concrete advanced, four longitudinal rows of porous tile were laid under it about equally distant from the walls and from each other, and about 1 foot below the clay, and were covered with broken stone. These tiles were carried to within 9 or 10 feet of the front wall, where they were connected with a 6-inch tile, which, finally, was carried under the front wall and connected with a vertical 15-inch sewer pipe, the top of which is flush with the sidewalk.

After the concrete was in place it was coated one-half inch thick with Portland cement plaster, composed of equal parts of cement and

sand. In the upper 7½ feet of the walls, Utica cement was used in place of Portland.

The brick wall was laid in Utica cement mortar, made of equal portions of sand and cement. At the corners, the brick-work was carried out square, leaving a space between it and the rounded corners of the concrete wall. This space was utilized in one corner to carry the overflow-pipe, 15 inches diameter, which led to the river. Its flow-line, where it entered the reservoir, was 2 feet below the top of the walls.

The roof is 2 inches thick. It rests on concrete arches, which span the entire width of the reservoir, 55 feet.

The ribs are 7 feet apart from center to center, except that between the rib at each end and the gable wall the space is 9 feet 6 inches.

Wedge-shaped blocks, 6 by 6 inches at base and 2 feet long, were used in forming the recesses for the feet of the arches. When the false

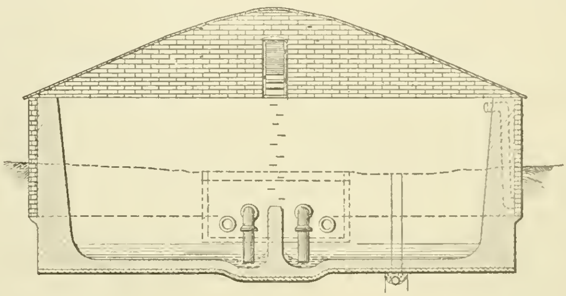


Fig. 5
SECTION C D.

work for the walls was removed the wedges were taken out and ½-inch cast-iron plates were placed in the bottom of each niche.

Seven-inch channel irons, bent to form the intrados of each rib and lightly spliced in the middle, were put in place, their feet resting on the cast-iron plates, and then wrapped with expanded metal lath throughout their entire length.

The false work for the roof, supported by five lines of 6 by 6-inch posts, was then erected, and the molds for the ribs were filled with concrete, varying in depth from 10 inches near the crown to about 4 feet near the walls. Expanded metal lath, 2½ inches mesh, was spread over the entire surface of the roof, and concrete of one part cement, two of sand, and five of gravel, to a depth of 1½ inches, was spread over the lath, and finished with a ½-inch coat consisting of 2½ parts sand to 1 of cement. The cement in each case was German Portland.

When the false work was removed a thin coat of cement plaster was spread over the entire structure on the inside. All the iron-work

was covered with the thin coat of cement, except the tie and suspension rods, which are painted.

The roof was placed in November last, and it was thought best to keep the false work in place until all damage from frost, if any, could be repaired. The repairs were made in May last, and the plastering was done at the same time.

The ribs were examined as the wedges on the false work were taken out; but no appreciable settling could be discovered. What was considered the weakest rib, was loaded with earth 1 foot deep and 7½ feet wide for one-half its length. This was left on for two weeks; but no settling greater than one-eighth inch was observed. Samples of the earth were weighed, and it was found that this section of the roof was carrying 110 pounds per square foot.

Fig. 6

When designing the roof, an experimental rib, shaped like the proposed rib, 3 inches wide and 2½ inches deep at the crown, with a span of 8 feet, was made of a concrete having about the same proportions as that used in the roof. It was left in moist sand for two weeks and then loaded at the crown until it broke. The breaking load was 300 pounds.

Before breaking, it buckled in the upper third of its half length. To provide against such failure in the actual ribs I placed two rods ¾ inch diameter, 12 feet long, about 2 inches below the top of the rib on each side, covering this weak place. Their upper ends were about 5 feet from the center. One barely perceptible crack has appeared in each rib at the crown and running parallel with the rib. This may or may not be due to contraction and expansion.

It is intended during the summer to put a coat of pitch on the roof in order to fill the fine cracks, and to prevent rain and snow water from soaking into the concrete.

The ventilation is effected through the doors in each end. The upper part of each door is fitted with Z-irons, so placed that bats or birds cannot enter, or sticks forced through, so that any dirt falling upon the ventilator will be thrown out.

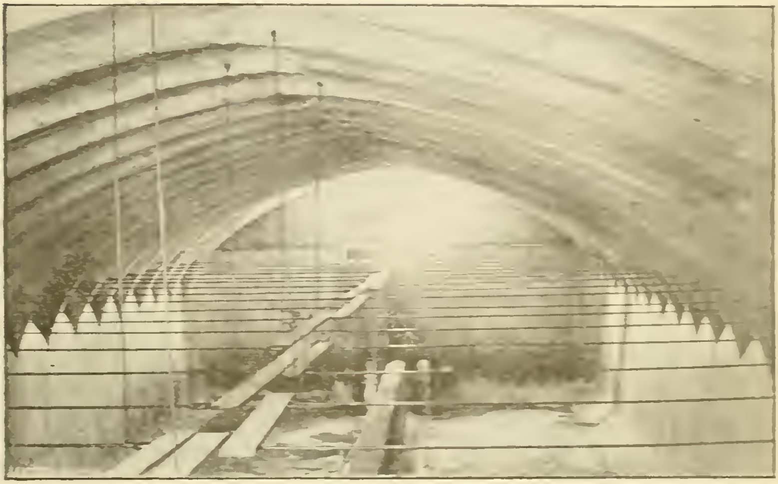


Fig. 7

The cost of the reservoir was as follows:

Excavation	6,144 cubic yards, at $ .50	$3,071 00		
Clay puddle	86 " " 2 50	215 00		
Crushed stone	11 " " 2 50	27 50		
Portland concrete	1,275 " " 6 50	8,2[illegible]		
American concrete	348 " " 4 00	1,392 00		
Finishing coat	1,891 square yards, " .75	1,418 65		
Brick work	104.5 M. " 20 00	2,091 03		
Inspection		457 00		
Iron work (tie rods and bearing plates)		107 15		
			$17,[illegible] 51	
The roof contract		$2000 00		
Sand, 180 loads, at $1.12		201 60		
Labor, inspection, etc.		580 27		
			$2,781 87	

This shows the cost of the roof to be less than 27 cents per square foot, including the ribs.

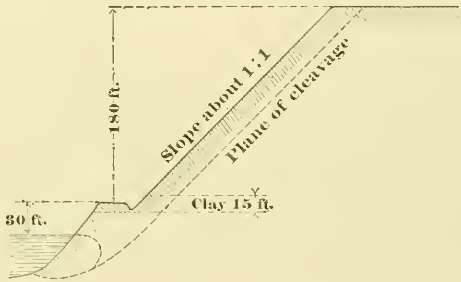
THE CONTRIBUTION BOX.

Members of the associated societies, and other persons, are invited to send to the Secretary, for this department of the JOURNAL, such matters of general interest as may come to their notice.

Hydraulic Excavation of a River Bluff.

Mr. Don J. Whittemore, Chief Engineer of the Chicago, Milwaukee and St. Paul Railway, sends the following interesting account of his experience in excavating a bluff by means of a hydraulic jet:

The line of our road at Sioux City follows along the river, and in and under the bluffs for a distance of over one mile. The roadbed was constructed by cutting a notch in the bluff-side, about 30 feet above the level of the river. (See sketch herewith). The bluff-slope extends from grade to a height of from 100 to 180 feet. The



Missouri River undercut our roadbed, and within an hour after passing over it with a passenger train, a section of 800 feet in length slid into the river. The plane of cleavage was about 15 or 20 feet back of the face of the slope. To restore the roadbed, our Company secured, by my advice, hydraulic machinery, and, at the close of 1883, we had washed some 300,000 yards into the river, and had formed a roadbed sufficient for restoring the track. During the summer of 1884 we prosecuted the work still further, and removed from the bluff into the river about 700,000 yards, at an expense of 2½ cents per cubic yard. The bluff being so high, it was dangerous to employ the water-jet without having at all times complete control of avalanches. This was accomplished by the employment of powder in throwing down material when it had become sufficiently undercut by the water-jet, and before there was danger of an avalanche, unaided by other forces than gravity. The amount expended for powder was about 1 cent per cubic yard of material moved, leaving the actual cost of hydraulic excavation, exclusive of powder, 1½ cents per cubic yard. All the material thus moved was not of the general character of bluff material along the Missouri. Just at and above grade, there was a streak of pretty tough clay, that varied in thickness from 10 to 15 feet, and in this the water-jet would not work until the clay had become disintegrated by powder. Were it not for this clay, and for the necessity of controlling avalanches, I am sure the work could have been accomplished for about 1¼ cents per cubic yard.

Engineers in charge of improvement of the Missouri and Mississippi Rivers have had remarkable success in the use of the water-jet, and I am surprised that

some of our members have not heretofore published full accounts of such work. Meagre accounts can be found, I think, in some of the publications of the United States Engineer Department.

Mr. Corthell and the International Institute.

Mr. E. L. Corthell writes from Berne, Switzerland, that he is recovering from his illness, and that he hopes soon to be well again.

Copies of his proposition for an International Institute of Engineers and Architects have been sent out, with accompanying letters, to 133 engineering societies and 147 individual engineers, a total of 280 copies sent to thirty-four different countries. About fifty copies have been sent also to architectural societies in the United States and other countries.

The More Important Advances in American Railroads.

Under this title, Mr. O. W. Petri, in an address delivered before the Society of German Iron-masters (Verein Deutscher Eisenhüttenleute), and at Düsseldorf, and printed in *Stahl und Eisen*, sums up a number of important facts having reference to the progress in railroading which this country has witnessed during recent years.

Mr. Petri, who rejoices in the title of Regierungsbaumeister (which, for want of a better definition, might be rendered into government-master-builder), visited this country with his fellow-members of the Verein, in 1890, and the notes here presented were, no doubt, largely compiled during that visit.

These are confined chiefly to methods of operation and their results, notably in the direction of the reduction of freight charges, a reduction, which, during the twenty years from 1870 to 1890, amounted to more than 50 per cent.

Mr. Petri finds that, while scientific education of engineers is not so general here as in Europe, this lack is largely compensated by that practical ingenuity which knows how to make the best possible use of the materials at hand, a faculty of the first importance, especially in railroad operation.

The organization and operation of the Pennsylvania Railroad are taken as those of a model corporation, and are described in some detail.

Barbadoes Railway.

Mr. Walter Merivale, C.E., of Ely, England, Member of the Institute of Civil Engineers, having recently been appointed in charge of a narrow-gage railway, built some ten years ago in the island of Barbadoes, has recently completed a survey for a proposed light railway encircling the island. He proposes to use 40-pound rails on steel sleepers, and to adopt 2 per cent. as the ruling gradient, and 300 feet as the minimum radius of curvature, and to equip the road with 14-ton, 6-wheeled locomotives, having leading and trailing pony trucks, and with light cars, similar to those used on city passenger railways.

The estimate submitted is based upon the use of the public highways, although Mr. Merivale advises against such use, on the ground of liability for accidents, restrictions to speed, necessity of stoppages to permit the passage of vehicles, and the expense and inconvenience of restrictions as to design, and because the use of the highways would lengthen the line about 4 per cent., and would entail far steeper grades and sharper curves than would otherwise be necessary.

THE LIBRARY.

It is proposed to notice briefly in this department of the JOURNAL such engineering publications as may find their way to our shelves.

Publishers are requested, in sending works for review, to state the prices of same.

Roofs and Bridges. A TEXT-BOOK ON —. Part III; Bridge Design. By Mansfield Merriman, Professor of Civil Engineering in Lehigh University, and Henry S. Jacoby, Associate Professor of Civil Engineering in Cornell University. 425 pages, 5½ x 9 inches. No index. New York: John Wiley & Sons. 1894. $5.00.

In the preface to the first and second parts of this text-book, Professor Merriman states that "the course of instruction in roofs and bridges given to students of civil engineering in Lehigh University consists of four parts: first, the computation of stresses in roof trusses, and in all the common styles of simple bridge trusses; second, the analysis of stresses by graphic methods; third, the design of a bridge, which includes the proportioning of details and the preparation of working drawings; and fourth, the discussion of cantilever, suspension, continuous and arched bridges."

The first and second of these parts were treated respectively in the first and second parts of the text-book, and the third forms the subject-matter of the part now before us.

As the authors truly say, "The computation of stress in the principal parts of a bridge-truss is the least part of the work of design," and it is, therefore, not surprising to find this volume, which relates to the other portions of the subject, containing nearly twice as much matter as the two preceding volumes combined, or to note that the blank pages, interleaved in the first two volumes, are omitted in this.

Another innovation, which marks the present volume, is the contribution of numerous chapters by other writers than the authors proper. For instance, Mr. Jarvis, President of the Berlin Iron Bridge Company, contributes a chapter upon "Bridge Shops and Buildings," based upon the plant of that company, and Mr. Samuel Tobias Wagner, formerly Superintendent of Shops for the Phœnix Iron Company, one on "Shop Practice;" Mr. George H. Thomson describes a "Ballast-Floor Plate-Girder Bridge on the New York Central and Hudson River Railroad;" Mr. Charles S. Churchill, a "Half-Through Skew Lattice Bridge on the Norfolk and Western Railroad;" Mr. C. C. Schneider, two bridges erected by the Pencoyd Bridge and Construction Company; Mr. C. S. Maurice, one erected by the Union Bridge Company; Mr. John Sterling Deans, one by the Phœnix Bridge Company; and Mr. O. J. Marstrand, formerly Assistant Engineer of the Brooklyn Elevated Railroad, contributes a chapter on "Elevated Railroad Structures." The work concludes with a chapter describing a highway bridge for electric railway traffic at Hokendauqua, Pa., including an account of damage caused to the bridge by an exceptional flood.

Little effort has been made to separate the theoretical and practical portions of this work, so that theory and practice may be said to go literally hand in hand in the volume, as they should in fact. The opening chapter is devoted to the history and literature of the subject, and it is significant of the curve which the history

would plot, that the three periods, of which this portion treats, are those prior to 1800, from 1800 to 1850, and subsequent to 1850, respectively.

In treating of the bibliography of the subject the authors take occasion to remark that, "The Descriptive Index of Current Engineering Literature, published by the Association of Engineering Societies, gives many pages of titles of such articles, with brief notes of their contents, and this should be at the hand of every student who desires to become well informed on the progress of bridge development."

Nearly one-half, and perhaps the most important part, of the treatise proper, is devoted to an analysis of the design of four different trusses, namely, a triangular roof truss with wooden compression members, a plate-girder bridge of 80 feet span, a pin-connected truss of 142 feet span, and a riveted triangular truss of 80 feet span for highway purposes. In treating of the last three structures the authors make use respectively of Mr. F. H. Lewis' Specifications, published in the *Proceedings of the Engineers' Club of Philadelphia*, Volume IX, January, 1892, and of Messrs. Cooper's and Waddell's Specifications respectively.

The portions written by the authors are marked by that careful, severe, common-sense style which characterizes the first two parts, and the rest of the work gives evidence of their careful supervision.

Transition Curves. A Field Book for Engineers, containing Rules and Tables for laying out Transition Curves. By Walter G. Fox, C. E. New York: D. Van Nostrand Co., 1893. Van Nostrand's Science Series, No. 110. 80 pages, 3½ x 6 inches. 50 cents.

This little work consists essentially of six tables for as many different transition curves, with the explanations necessary for their use. The curves are laid out with chords of 10 feet, and the degree of curvature in each case increases directly as the number of chords run. In the first table, the increase of the degree of curvature for each chord is ten minutes; in the second table, twenty minutes; in the third, thirty minutes; and so on, until in the sixth and last table the increase is one degree.

The author has calculated the co-ordinates for the ends of the ten-foot chords in each of these curves, and the tables give not only the angles to be laid off from the transit, but also the latitudes and departures of these points, so that the curve may be located by offsets, if desired. The tables give also the total central angles subtended by the transition curve up to each point, the long chord at such points and a column of corrective multipliers to be used in finding the apex distance. Tables of radii corresponding to different degrees of curvature, and of apex distances for a one-degree curve, similar to those found in other works, are also given.

Theoretical Mechanics. An Elementary Treatise on —. By Alexander Ziwet, Assistant Professor of Mathematics in the University of Michigan. Part I: Kinematics; 181 pages; 5½ x 9 inches. And Part II: Introduction to Dynamics; Statics; 183 pages. New York: Macmillan & Co., and London, 1893. $4.50.

The practice of furnishing magazines to their subscribers with the edges uncut, is explained by the fact that, when they come to be bound, they must be trimmed, and that, if they have been already cut, the two trimmings might reduce their margins to an undesirable extent. It is difficult, however, to see what reason can be assigned for furnishing a bound volume with uncut edges, unless it be the book-fancier's fond-

ness for this sort of thing, and we submit that these gentlemen are hardly likely to consult a work like the one before us.

While the author claims to have kept constantly in mind the particular wants of engineering students, aiming to make the work serve as a preparation for the practical application of the science of mechanics, it concerns itself essentially, as its title implies, with the subject of theoretical mechanics; and, while the assimilation of its contents would, no doubt, give a high degree of flexibility and adaptability to the mind of the student, and especially to that of the student of mechanical engineering, one cannot help regretting the fact, if it be a fact, that it is nowadays necessary to learn so much which must be speedily forgotten.

The author has sought to adapt his work to the requirements of American colleges and universities, where, as a rule, the student does not take up the study of mechanics until he has already acquired a knowledge of the elements of higher mathematics, whereas, in England, the reverse of this is generally the case. The higher mathematics are, therefore, freely used.

Society Proceedings.

American Society of Civil Engineers. Transactions of ——.
July, 1894. Vol. XXXII, No. 1.

In this number is continued the publication of papers read before the Annual Convention of the Society, held at Niagara Falls in July. Prominent among these are Mr. William B. Landreth's account of the Sewage Disposal Works of Chautauqua, N. Y.; the Cippoletti Trapezoidal Weir, by Messrs. A. D. Flinn and C. W. D. Dyer, Steam and Electric Cableways for Logging and Canal-Boat Towing, by Mr. Richard Lamb, with discussion by Mr. Spencer Miller; Brafford's Ridge Tunnel, by Mr. Charles W. Staniford; and The Load Line in Telephone Exchanges, by A. V. Abbott.

August, 1894. Vol. XXXII, No. 2.

In this number, which comes to hand as we go to press, we find a second installment of the papers read before the Annual Convention, at Niagara, in June last. We have here Mr. Crandall's elaborate paper on "Friction Rollers," illustrated with diagrams showing the results of experiments for determining lines and intensities of stresses by means of polarized light; Mr. John W. Hill's paper on the "Quality of Water Supplies;" Messrs. Campbell and Abbott's illustrated Description of the Tequixquiac Tunnel, Mexico; a handsomely illustrated description of the Sand-rock Sewers of St. Paul, Minnesota, by Mr. George L. Wilson, President of the Civil Engineers' Society of St. Paul; and the very seasonable papers of Mr. L. L. Buck on the "Niagara Gorge," and of Mr. Wallace C. Johnson on the "Pulp Mill of the Cliff Paper Company of Niagara Falls."

Mr. Buck's paper, with its map of the locality, formed a convenient *vade mecum* for the visitor at the Falls, and Mr. Johnson's paper afforded a very interesting description of the older hydraulic installation at that place, with some of its recent developments.

ASSOCIATION

OF

ENGINEERING SOCIETIES.

Organized 1881.

VOL. XIII. OCTOBER, 1894. No. 10.

ORGANIZATION AND MANAGEMENT OF A CITY ENGINEER'S OFFICE.

[Papers and discussions presented at meetings of the Boston Society of Civil Engineers, held January 24 and February 6, 1894.*]

BY ALBERT F. NOYES.

THE answer given to an inquiry as to what were the requisite qualifications of a successful engineer, was, "Common sense and a knowledge of mathematics, with a good deal more of common sense than mathematics." If this answer is applicable to one part of the profession more than to another, it is to the successful city engineer.

The engineer, as a municipal officer, has to do with the construction and maintenance of the public works, and has a certain control over the actions of private individuals and corporations.

When it is considered that the expenditures made by municipalities are largely for sanitary and other public works, that the proper design, the economical execution and the success or failure of these works are dependent upon the skill of the engineer and upon the attention given by him to their execution, it will be seen that the office of the municipal engineer is of the greatest importance to the community.

Until within a comparatively few years he has not been recognized as an executive officer of a community, and even to-day he is not so recognized in many of the smaller municipalities, his services being required merely to give lines and grades, to make computations or

* Manuscript received August 13, 1894.—*Secretary.*

surveys. The design and execution of the work are largely made by so-called "practical men," or under their direction. While a case of failure of any detail of work designed or executed by an engineer counts for more than a dozen similar failures in the work of the "practical men," the commonly received opinion that the engineer is not practical in the design and execution of the work under his charge, is not entirely undeserved.

I trust that some of the suggestions here made may have an influence in crystallizing the practice and the form of organization of the city engineer's department, especially in the smaller municipalities, thereby increasing the confidence of the community in the engineer and extending the field of his usefulness.

It is beyond the ability of any one man to become an expert in all of the branches into which the profession is being gradually subdivided, or to grasp their details.

As the volume of work required in the various branches increases, this process of subdivision continues, and, in order to reach the highest degree of efficiency, the work of the engineer of the future will be confined to a special branch or subdivision.

The work of the municipal engineer of the present day requires a large and varied experience, unremitting labor and attention, and constant study.

He is expected to be familiar with every branch of engineering, and to keep informed as to the latest engineering practice.

He is expected to be able to estimate the cost of any form of construction, from a drain or culvert to the most intricate piece of machinery of the latest design, and to be responsible for its proper construction and efficient operation.

He is also expected to be able to carry out all measures which may be required of him by the municipal government under whom he may be serving, however these may vary in their nature.

Civilization and the apparent opportunity to obtain a larger return for a given service, induce people to congregate in cities and towns. The growth in population of most cities and towns has far exceeded the most sanguine expectations of their founders, and few, if any, of the engineering works that have been constructed are of sufficient capacity for the requirements of the future.

A large portion of the expenditures of cities and towns is made in correcting the innocent blunders of men who have failed to appreciate and provide for the requirements of a rapidly increasing population and for the demands of a modern civilization. Most engineers can recall numerous instances where they have been prevented from carrying out much-needed improvements by the expense made necessary by lack

of breadth of conception on the part of the designers of the original work.

According to the census for 1890, 448 cities in the United States had a population of over 8,000 persons each.

There were

16 first-class cities with a population of over 200,000 each.						
12 second-class cities with a population between 100,000 and 200,000 each.						
30 third-class	"	"	"	"	50,000 and 100,000	"
390 fourth-class	"	"	"	"	8,000 and 50,000	"
448						

For convenience I would make a still further classification, limiting the fourth class to cities having a population between twenty-five and fifty thousand each, and establishing a fifth class, comprising cities having a population under twenty-five thousand.

The form of organization of the engineering department, or the department of public works, in most of our cities, has been a matter of growth, and in but few cases has the best plan for each city been studied out and adopted in the first place. But for the high personal character and ability of the officers having charge of the work, the defects in organization would be more frequently apparent. Even as it is, inefficient management, a lack of united action on the part of the executive officers, and an inadequate return for the expenditures made, are the rule rather than the exception.

It will undoubtedly be admitted that the proper execution of municipal works and economical results in operation can be obtained only by the concerted action of all in authority.

The work devolving upon the city engineer's department may be divided into the following principal headings, with their various subdivisions:

Highways, which may include surveys, the establishment of lines and grades, construction and maintenance, street and steam railways, street lighting, scavenging, street watering and cleaning, and the removal of snow; Water Supply, which may include the supply and the distribution; Sewerage, which may include the collection and disposal of house drainage, surface and sub-soil drainage; Bridges, which may include their design, construction and maintenance; Public buildings, which may include their design, inspection and construction; Parks and cemeteries, which may include their laying out, construction and maintenance; and Administration, which may include the general supervision of the work of the other departments, the law as it relates to the various works in hand, the supervision and execution of contracts, and attendance on committees or on the legislative bodies of the municipalities.

In fact, the city government of to-day is in a large measure a matter of municipal engineering, and the character of the city engineer's department is a safe index to the intelligence shown in the development of a municipality.

While the various cities and towns may differ widely in their location, topography, soil and climate, and in the habits of the people, there is no single form of government which can be shown to be the best for all, or which can even be applied to all; but there are a few general principles which can be made to apply to all cases.

In the larger cities each branch of work becomes a department in itself, and can best be executed in a satisfactory manner by an officer giving his exclusive attention to it.

It is acknowledged that the best type of organization for a first or second class city is that of St. Louis, Mo., where the public works are managed by a Board composed of expert engineers, each in charge of a division, who are classed as Commissioners.

The Commissioners are conversant with the work to be executed, and they meet as an executive body, where each has a voice in the direction of that work. Their deliberations are presided over by the Engineer Commissioner, who is President of the Board.

This form of organization, modified to meet the more limited requirements of the smaller cities, might well be adopted by them.

Next to St. Louis, Providence, R. I., probably presents, in its City Engineer's Department, the best form of organization. The City Engineer here takes the place of the Engineer Commissioner of the Board of Public Works. Each of the departments is managed by an expert engineer, who is dubbed Assistant Engineer in charge of department, and is under the immediate direction of the City Engineer, and accountable to him. In St. Louis, each member of the Board of Public Works joins in the transaction of the business, and has a voice in determining the policy of the other departments; while in Providence the City Engineer is the Chief Executive officer of the department.

In many cities of the third and fourth classes, the volume of work in the various branches is not sufficient to warrant the employment in the various departments of assistants who have had a broad experience sufficient to justify the placing of full control in their hands; while in many cities of the fifth class, which may include even the smaller towns, the volume of work is not sufficient to justify even the placing of an experienced engineer in charge of the municipal work.

In many of the municipalities of the last two classes the engineering work is performed by local surveyors or by engineers of but limited experience in the execution of the work required. The work is parcelled out to different persons, and thus, while the total volume and

cost of work performed may reach a very considerable amount, but few notes or records are left to show what had been done.

In many of our growing towns and smaller cities a person applying to the proper officer for permission to see certain plans is handed a bundle of miscellaneous plans, sometimes taken from a portable safe, but oftener from a shelf in a closet, with the remark, "There are all the plans we have. You can look them over, and if you find what you want, all right."

The bundle is usually found to contain a miscellaneous lot of plans, platted on various scales and of miscellaneous sizes, usually conveying a minimum amount of information. Such profiles as there may be are usually found to be platted from levels referred to a local, assumed datum, which cannot be reproduced, and the levels which may have been taken cannot be compared with each other.

In 1874, when the City Engineer's Department of Newton was established, although several thousands of dollars had been expended each year for engineering, less than one hundred plans were on file, and these conveyed so little information as to be of but little use.

The necessity for a more systematic organization and for a broader conception of the requirements of the smaller cities and towns, has long been apparent.

I would suggest, as a desirable form of organization, that the best local engineer or surveyor, whose services can be obtained at a fixed sum per diem, should be engaged to give so much of his services as the city or town may require. When so employed he should be at liberty to undertake such other work as he can perform without interfering with the municipal work. He should be given the title of city or town engineer, and an office in some public building, where all records, notes and plans belonging to the city or town, may be kept. He should be made responsible for their safe keeping, indexing and proper classification.

This service might be given in lieu of office rent, or as a consideration for being given all of the municipal engineering work, or he might be paid a certain fixed sum, dependent upon the amount of work to be done. He should have to do with, or have charge of, all the public works. By this course the municipality insures to itself the best continuous service with the least expenditure of time and money. An engineer so engaged will be best acquainted with local requirements, and will have a live interest in the welfare of the municipality and in its proper development.

There would be less likelihood of mistakes than by the usual methods, and the work of development can be more systematically carried on. It is not to be expected that a person whose services can be

obtained in many of the smaller cities or towns will have had the broadest experience in the various branches of municipal work he may be called upon to do, nor can it be expected that he will be informed upon the latest practice in all these branches. I would suggest that this higher order of service might be obtained through an officer who might be known as a consulting municipal engineer.

He should be an engineer of wide experience in municipal work, and able to grasp quickly the nature of widely varying local requirements. He could, to advantage, be retained by a number of the smaller municipalities, and be expected to visit and examine their works from time to time, and to advise the city or town engineer or surveyor upon many of the minor details of office management, accounts, records and methods, as well as to advise upon any special public work. It would also be desirable to have the approval of the consulting engineer upon the plans for the various works to be executed.

The services of the consulting municipal engineer might be employed to advantage in cities of a higher class, where the volume of work is not sufficient to warrant the maintenance of a Board of Public Works similar to that of the city of St. Louis, or the placing of the various departments in charge of special assistants, as at Providence.

The advice and assistance of the consulting engineer would be of the greatest value to the local engineer. The latter would have the advantage of the former's criticism of his plans and work. This would tend not only to insure the successful execution of work, but also to instil confidence into the mind of the public as to the practicability and the probable success of the execution of the plans. At the same time, the retention of such an officer by a municipality would constitute no acknowlment of lack of confidence in the local engineer. The municipal work will always, in the mind of the public, be that of the local engineer. The fact that another engineer was called in to advise him is soon forgotten, and the successful execution of management of the work is placed to his credit.

For a number of years it has been my practice, in the execution of the various works which I have had in hand as a city engineer, to consult other engineers of larger experience in each special class of work.

The advice thus obtained, while in many cases it has made no change in the designs, has given me greater confidence in the successful execution of the work as proposed.

This practice has at times assisted me also in obtaining favorable action of the City Council in making appropriations, in passing orders or in approving plans for proposed improvements.

I have at no time found that I suffered loss in their estimation.

On the contrary, the knowledge that I sought such advice increased their confidence in the department, and assured them that plans would not be presented to them unless I was sure they were right.

I am pleased to see that other municipal engineers have been quick to perceive the advantage derived by retaining the services of a consulting engineer, thereby obtaining more perfect results for the municipality and increasing the confidence of the community in their good judgment.

The confidence of the public in the engineer has increased, until to-day but few works of importance are inaugurated without first calling upon his services. Within the last twenty years nearly all of the larger municipalities have maintained engineering departments of greater or less efficiency, and the compensation for the services of the engineer has increased from 50 to 100 per cent.

Mr. William E. McClintock.—Mr. Noyes' paper has covered the ground carefully, and exactly as I like to see it done.

Some fifteen years ago I was called upon to lay out a system of sewers, and I then felt that I wanted some advice from an engineer of larger experience than myself. This help was refused me by my committee on the ground that I was paid to do all the city work, and that I should understand all about it. By hard work and by worrying my neighboring engineers, I succeeded fairly well.

A few weeks since, I received a call from the city engineer of one of our suburban cities who found himself in the same predicament. His work had been largely on railroads, and he had become expert on such work, but on sewers he had had but little practice. He was seeking light on his own account, as the committee had refused to allow him to contract a bill on behalf of the city. The problem was a comparatively simple one, but the best arrangement of sewers and outlets seemed difficult to decide upon. The town had ordered a combined system, without considering that the outlet was to be into the Metropolitan sewer, which would only allow of the discharge of the dry-weather flow. This would require a storm overflow into tide water, and would make a connection between the main sewer and the harbor, which was impracticable without a large storage basin. The construction of the basin and of the storm sewers would add very largely to the cost of the work, and they would not be satisfactory in their working.

All that was needed was the mere suggestion that the storm water be excluded.

In another case I was called to look over a system of sewers designed by the city engineer. In this case the engineer had placed himself on record for a combined system of sewers, throwing out entirely the use

of the natural water courses which were convenient for removing storm water. It was the duty of the consulting engineer to report a scheme which, in his opinion, would give the best results for the least money. The saving of $200,000, effected by these recommendations, placed the city engineer in an unenviable position, for his opponents made the most of it.

He was not to be blamed for laying out a combined system, for that was the order of the city government, but if he had attempted to lead he could easily have convinced them that such was not the better scheme. In this case, the consulting engineer should have been called in while the study was being made, and before the engineer or the committee had gone on record. The public would then not have known of the change and could not have found fault.

Still another case is that of a town where there was no storage in or near the village. This fact was brought to the attention of the town's people by a large fire which occurred at a time when repairs were being made on the water main and which caused great damage on account of the delay in procuring water at first. In this case the town would have made a good investment of the fees of a competent consulting engineer.

Another work which demands good judgment at the start is highway engineering. Four years ago there was a general feeling among the road officials of the smaller towns throughout the State that they did not want any city fellow telling them how to build a road. The old prejudices are being gradually broken down, and to-day no class of men welcome advice more heartily than these same men. To be sure, not all of them follow it, but if a few, by doing so, succeed in making a good showing, public opinion will soon compel the officers of adjoining towns to fall into line.

The Massachusetts Highway Commission, appointed a year and a half ago by Governor Russell, found itself from the first opposed by the County Commissioners, but at a convention of the County Commissioners of the State held in Boston this day, a committee was appointed to appear before the Legislative Committee and to advocate a highway bill even stronger than the one of two years ago. I cite this case simply to show that public opinion may be reversed by proper management.

If one attempts to follow public opinion he will surely get left behind. One must keep constantly just a little ahead until his perfected plans are carried out.

A committee which has placed itself on record will never change its mind. It should be convinced before it places itself on record, and it will then do whatever the engineer desires. The great difficulty is

that the consulting engineer is called in after the money is appropriated, and he is then expected to do the work without the means.

The engineer at large ought to be disabused of the idea that the city engineer is a mere surveyor, who merely gives lines and grades for the city work, and lets some other man carry it out.

The President.—Mr. Noyes in his paper referred to the organization of the City Engineers' Department of Providence as serving as a model of its kind. I will ask our Secretary to read a description of the organization at Providence which has been prepared by Mr. Clapp, of that office.

THE CITY ENGINEER'S OFFICE, PROVIDENCE, R. I.

By Mr. Oris F. Clapp.

The first City Engineer of the city of Providence, Mr. Charles E. Paine, was appointed by the City Council, January 1, 1872. This gentleman had performed the duties of the office, so far as the giving of street lines and grades, for about five years under the unofficial title of City Surveyor. Previous to that time the city, like a large majority of towns and small cities, had no regularly employed engineers, but each committee of the city government having occasion to use such help, had ordinarily employed such of the local engineers or surveyors as the kind of work at hand seemed to require. The plans made for such committees, being put upon record in the Recorder's office or kept by the city clerk in various drawers and closets, were all that the city retained. The notes taken were kept by the parties employed, and were often used again on other occasions for the city, or in his private practice. At the time the office was created, the Providence water works had been under construction for about two years, and the question of sewerage was becoming prominent. The construction of sewers was put into the hands of the Water Commissioners as a committee, and the engineering force of the water works, already effectually organized under Mr. J. Herbert Shedd as Chief Engineer, was increased to include this new department. Upon the completion of the water works in the spring of 1877, the engineering departments of the city were consolidated, and Mr. Samuel M. Gray, who had been engaged upon the construction of the water works, was appointed City Engineer on February 5th.

The Water and Sewer Departments were continued as already organized by Mr. Shedd, and the other departments now existing were organized by Mr. Gray out of the original City Engineer's office. Although direct control of the office passed from the City Council to the Commissioner of Public Works on May 2, 1890, when Mr. Shedd

was appointed City Engineer, the organization of the office, as completed in 1877, has remained to the present time practically the same. It consists of a City Engineer, appointed annually by the Commissioner of Public Works and confirmed by the City Council, a chief clerk and two assistants, with an average for the past year of sixty-nine engineers and students distributed among the following seven departments: Bridges and Harbor; City Property; Highway or Grade; Parks and Public Buildings; Sewer; Street Line; Water.

To any one familiar with municipal engineering the names of these departments indicate the character of the work performed by each of them, but a somewhat detailed enumeration of the duties of each department may not be out of place.

Bridges and Harbor.—The duties of this department consist in making an annual examination of all bridges under the care of the city; the preparation of plans and estimates for all new bridges and for the repair of old ones; keeping detailed accounts of all expenditures of whatever kind for each bridge; looking after maintenance and repairs, nearly all of which is done by day's work, by a force the nucleus of which is permanently employed for that purpose; making out pay-rolls for all employees, such as keepers, engineers, carpenters, laborers, etc.

During the last two or three years this department has had charge of building the walls of the Woonasquatucket and the Moshassuck Rivers through the Cove Basin. Last year a contract for building the bridge abutment and the adjoining river walls for a bridge over the Providence River at the end of Exchange Place was taken from the contractor and the work done by the day under the direction of this department. Plans for a new city wharf were made and its construction was superintended. More or less dredging is done every year in the river and harbor, and this necessitates numerous soundings in order to estimate the amounts removed. This department has a self-registering tide-gage, the records of which are carefully preserved. The bridge department makes a separate report each year to the City Council.

City Property.—The City Property Department surveys each piece of property bought, sold or exchanged by the city, makes maps of such properties for record, looks up the titles and writes the deeds, places stone bounds to mark the corners of lands owned by the city, etc., etc. The exchange of lands between the various railroads and the city, in connection with the improved terminal facilities, has largely increased the work of this department during the last two years.

Highway or Grade.—The Highway or Grade Department prepares all plans and profiles made for the purpose of defining street grades,

and, when these have been established by the Board of Aldermen, makes finished plans for the city clerk for record. It marks all grades for houses and fences, and for the construction or curbing of streets, the paving of gutters, etc.; prepares plans, specifications and estimates for building or rebuilding streets; makes curbing assessments and measures all work done by contract.

Parks and Public Buildings.—This department prepares plans for the treatment of all minor parks; does all staking out for construction of same and measures up all work done; prepares plans for improving school estates, building retaining walls, grading, draining, etc., for the committee on Public Buildings, and stakes out lots, paths, etc., for the Superintendent of the North Burial Ground, which is owned by the city.

Sewer Department.—The Sewer Department prepares all general sewerage maps, estimates of cost of sewers as called for by the sewer committee, and plans and specifications for letting work. It looks after the engineering and inspecting of the construction, making out estimates, bills for extra work, pay-rolls of inspectors, etc. It keeps office records of all work done, and has general oversight of inspectors of private drains. It keeps records of these drains for general use, makes plans and calculations for sewer assessments, and has general oversight of sewer maintenance.

During the last four years a large amount of work has been done on what is known as the Improved Sewerage System, which is more correctly the intercepting and collecting system. A special appropriation for this purpose has been made.

Street Lines—This department makes all surveys for the laying out of new streets, and for the widening, straightening or relaying of old ones, makes plans for record of each establishment of line or layout, and gives lines for all buildings or fences abutting upon the street.

Water Department.—The Water Department makes all plans and estimates for water-pipe extension, marking lines and grades when necessary, sizing service pipes and keeping record of the work done, the water used, analyses made, etc. It has the general oversight of the pumping stations, reservoirs, etc. The meteorological records are looked after and tabulated. During the last few months extended experiments have been made upon the filtration of water.

The average number of persons employed in these departments for the last year is as follows: Bridge Department, 8; City Property Department, 4; Parks, 8; Highway or Grade Department, 11; Street Line Department, 4; Sewer Department, 24; Water Department, 10.

The employees of the office are appointed, and their compensations are fixed by the Commissioner of Public Works, on the recommendation

of the City Engineer, and both their appointment and their compensation have to be confirmed by the Board of Aldermen.

The present heads of the several departments have, with one exception, held their positions since the organization, and several of the principal assistants were members of the office at that time. The others holding that position have been promoted from students. Students are admitted to the office to serve for three years at a nominal salary. The growth of the office during the last twenty-two years is rather interesting. In 1872, the first year of its existence, the number of persons employed was fourteen, and the expenditure $8,770.28. During 1877, the first year after the consolidation, the average number employed was thirty, and the expenditure was $38,441.38. During the next twelve years the number of persons employed averaged thirty-four, and the expenditures $38,061.19 per year; while during the last four years the average number has been fifty-six, and the expenditure $52,772.45 per year. Great as this increase seems, it is not disproportionate to the increase in population and to the work necessitated thereby.

In 1867, when the surveys were made for the present water works, the population was 56,000 and the area of the city about 3,700 acres. In 1868 this was increased, by the addition of a part of the town of Cranston, to a population of 64,000 and an area of 6,000 acres. Again, in 1874, two years after the office of City Engineer was created, a part of the town of North Providence was annexed, increasing the population to 96,452 and the area to 10,300 acres. The area of the city has remained practically the same to the present time, but in 1893 the population had increased to 148,942.

Public spirit has developed also, and the last few years have been marked by a large increase in enterprises calling for engineering help. About 329 acres have been added to the 163 acres previously devoted to park purposes. Within the last four years special loans amounting to $1,200,000 have been made for the construction of highways, and nearly all of this has been spent. During the same time the improved sewerage has called for appropriations of $3,500,000, of which $1,531,890.57 has been used. A new reservoir has been built for the high service, a new pumping engine is being built for the Pettaconset station, and an appropriation has been made for filtering the water used by the city.

The question of placing the designing of public buildings and the superintendence of their construction in the hands of the City Engineer is now being agitated.

The ordinance of 1877, fixing the duties of the new City Engineer, begins as follows: "Section 1. The City Engineer shall perform all such services for the city of Providence, as properly come under the direction of a civil engineer or surveyor. He shall be consulted on all matters

relating to public improvements of every kind where the advice of an engineer or surveyor would be of service. . . . . . ."

Mr. Lewis M. Hastings.—In considering this matter of municipal or city engineering it is interesting to note how recent a development of modern civilization it is.

Records and plans of public work, constructed in any but the most recent period, are either wholly wanting or singularly deficient in necessary information. The advantage or necessity of carefully preserved records of the construction of public works seems not to have been at all appreciated until very modern times. Thus, in the city of Cambridge, in which I live, although it was settled in 1630, it was not until 1837, or more than 200 years later that the first survey and plan of the streets of the then town of Cambridge was made and the first report on the widths and other conditions of the streets was rendered.

The first sewer was built in 1845, but not the slightest record or plan of this has ever been found. Many of the old plans of about that time seem to be the result of a studied attempt to avoid giving information. It was not until the office of City Engineer was created, in 1866, that records and plans at all adequate or reliable began to be made and filed. This is but a similar condition to that of many or all of the older cities and towns, and it is to be hoped that such discussions as this may incite the authorities of the younger communities to better care of existing records, and to more judicious and intelligent supervision of proposed works.

It seems to me that it will be extremely difficult to lay down any universal rule or principle for the organization of the city engineer's office, even in cities of the same size. The local requirements of the work vary greatly in the different communities; and indeed the work in the same office may vary largely from time to time, for various kinds of public work are usually carried out spasmodically and separately, requiring that the attention of the engineer be given at one period to *one* line of work, at another time to an entirely different one. A city may at one time make extensive additions to its sewer system, at another to its water supply, at another to street widening and improvement, at another some large bridges may be built. Now the organization of any office and the make-up and assignment of its corps of assistants (and I may add the organization of the city engineer's *mind* as well), must be so sufficiently broad and elastic as to meet these changing demands upon it.

While I believe thoroughly in the advantages of as close an organization and as systematic a division of work as the size of the office and the amount of regular work will allow, yet this principle may be carried

too far in a small office where the character of the work is intermittent and variable, and where there is not enough work of a given kind to keep an assistant continuously employed upon it.

I have found that when a person is detailed in that way for specific work he is apt, in a short time, to show a certain unfitness for and reluctance to undertake, even temporarily, work of a different nature, and he then works to disadvantage.

In many cases it will be best, I believe, not to attempt any high degree of organization of services, but to assign each assistant to that work for which he may be best adapted, as the kind of work may vary from time to time, requiring each one to keep posted in the general work of the department and ready to take up any work for which his experience may fit him, making him less of a specialist and more of a "general assistant." He will thus acquire greater flexibility and adaptability to varying conditions. I think that the place where a young man just entering the profession can best acquire a wide and varied experience in the different branches of municipal engineering, is in the engineer's office of a city of moderate size, where the organization is such as I have described.

In the larger cities, where the work is more nearly uniform in character and amount, some such plan as that in operation at St. Louis or Providence, modified to suit the local requirements, will undoubtedly be most suitable.

After all, it seems to me that the question as to organization best adapted to the required work in any given case, must be left largely to the individual skill and good judgment of the engineer in charge. On him will rest the responsibility of obtaining the best results for the city under the existing conditions, including in these what is often a very niggardly appropriation.

Mr. John T. Desmond.—My experience leads me to disagree with Mr. Noyes in his advocacy of the employment of a local engineer in small cities on the per diem plan. Too much of his time is taken up in answering questions, and in attending calls and committee meetings, and for this time no charge is supposed to be made. The payment of an annual salary, sufficient to cover these items, is better both for the city and for the engineer. The latter then feels that he is something more than a mere driver of stakes or a measurer of mechanics' work.

A city engineer who does not devote his whole time to the city, often finds himself trying to serve two masters. In many cases the engineer's client thinks that the engineer has a better "pull" with the city council than some other local engineer, and where his time is divided, the city engineer is supposed to consider private interests first. In a

certain case I was consulted as to the grade of a proposed street, and it was found that if my ideas were carried out, it would mean considerable expense to the parties consulting me. One of them told me very frankly that his only desire was to get his house lots on the market at the least possible expense, and that the purchasers of the lots could struggle with the grade question afterwards. I reminded him that the city would probably have to struggle with it after several houses had been built, and that heavy damages would have to be paid. He replied, "You are working for me just now, and not for the city." I declined to see it in that light, and he employed another engineer who would do his bidding; and the result to the city was as I had anticipated. In Mr. Noyes' paper is another suggestion which, however, as he admits, was not practised by himself, viz.: that of engaging the same consulting municipal engineer for all classes of work in small cities.

While I believe that the city engineer ought to have some voice in the matter of selecting a consulting engineer, there are times when it is advisable that he should waive that right, as, for instance, in cases where he might be suspected of selecting a friend to endorse his plans. But even in such a case the city engineer has a right to protest against the choice of a committee, when the man chosen is incompetent, when he has no standing in the profession, or when he is evidently disposed to be governed, not by the merits of the case, but by the bidding of those who engage him. Personally, I have always favored the employment of a consulting engineer on important work, sometimes rather in order to satisfy some doubting Thomas in the committee, than because I thought such services necessary. The result has always been satisfactory to all concerned.

Mr. A. F. Noyes.—As the city engineer becomes able to convince the municipality of the benefits to be derived from his services, there will undoubtedly be opened for him a wider field for advanced work. He should therefore insist upon being allowed to give to his work the thought and study necessary to make its results as perfect as possible, and upon being allowed also to obtain by consultation the advice of other engineers who may have had special experience in the kind of work being investigated, or greater opportunities for observing the results obtained by others. As a result of this practice, the position of the city engineer has been advanced from that of a surveyor giving merely street lines and grades to that of one of the highest administrative offices of the city, and in many of our best-managed cities the engineer practically takes charge of all of the public works, and in fact is in close touch with almost every detail of municipal government.

Since writing my paper I have had exceptional opportunities for

observing the great lack of system in laying out and executing the public works in many of the smaller municipalities, and the financial loss to which these municipalities are thus constantly subjected. From time to time I have met bright, enthusiastic and capable engineers who are called upon to advise upon the municipal work of the towns in which they live or of adjoining towns, and this work they attempt to do in addition to their regular duties of local land surveying and conveyancing. The local character of their work deprives them of the opportunity to become acquainted with the latest practice or with its results. They are enthusiastic in the execution of their work, and are glad to obtain information which will enable them to do that work more successfully. By availing themselves of the services of the consulting engineer they will become stronger men in the profession and of more value to their municipalities. An article recently published in one of our technical papers and giving the experience of a western engineer, illustrates the extent to which the services of the engineer are appreciated in many places and the difficulties he encounters in attempting to do good work and to secure the appreciation he deserves. The engineer in question received the compensation of two dollars per day, and he found it exceedingly difficult to get from the municipality permission to make any improvements. He finally succeeded in getting permission to grade one of the streets for a few blocks and to lay a sidewalk. The object-lesson thus given caused a complete revolution in the public sentiment, and after this no public work was entered upon without first consulting the city engineer. The article does not state whether or not this affected his salary. A member of a city council recently criticised the city engineer very sharply because he had expressed the wish to consult with an older engineer in regard to some of the details in designing plans for an extensive system of surface drainage. In another case the engineer was asked if he was not an engineer, and if he could not perform as well as any one else whatever was required of him.

Mr. G. A. Kimball.—In order to accomplish its purpose, the city engineer's office must command the respect of the city government and exert an influence in the community. The public mind must be disabused of the notion that the chief duties of the office are those of land surveying and driving stakes, and must be brought to look to the engineer for carefully-prepared and well-matured designs of public works and for advice as to the method to be followed in construction. The office must furthermore be so equipped that it can furnish competent executive forces for the management and execution of all work intrusted to it.

The collection of reliable data and its arrangement in proper form

for reference will tend to make the office valuable to the city government and to the public. This may be accomplished in part by collecting information in regard to the public works of the city, their engineering features, their cost, etc., making a record of all underground work, whether built by the city or by private companies, collecting plans of all surveys of city property and filing them in proper form; and preparing copies of all land plans from the registry of deeds and from other sources. In some cities and in many towns no plan or record can be found giving the location and depth of sewers, built and paid for by the city, and it is necessary to depend upon the old residents for this information.

Labor may be profitably expended also in collecting facts and figures in regard to improvements completed or in progress in other cities, with the methods of performing the work, the cost, the conditions, and other details. The methods adopted in different places for the maintenance of water-works, sewerage systems, streets, etc., together with the prices paid for work, will be important information to all members of the government; and will be of interest to citizens who are axious for the public welfare.

The city engineer's office which is in possession of all the facts respecting the public works of the city, which is well equipped with information in regard to the experience of other cities in the construction and management of public works, and which has in its possession facts and facilities for making reliable estimates, will make its influence felt in the city. Members of the city government, heads of departments and others, will then realize that at the office of the engineer they can obtain all the information necessary to guid them in their action upon questions which may arise in boards, committees, and other branches of the government, with regard to public works.

A library of carefully selected engineering works, so arranged and indexed as to furnish means for ready reference, will exert a beneficial influence upon all those who consult the office for information or advice on engineering questions. It will also be of great value to the several departments, and to the assistants and others who make up the working force of the office. The work of the city engineer's office is so broad, covering as it does nearly every branch of engineering, that a good library is absolutely necessary. The large library at the City Engineer's office in Boston may be considered a model of what such a library should be.

A wide field for study is open in the matter of economy in determining how little material may properly be used to accomplish a desired end. The frequently adopted rule of thumb or of "making it strong enough anyhow," may be a proper one for the so-called "practical man," but it is entirely out of place in the engineer's office. In some cities the

tendency to cheap and weak work is carried to excess, while in others material is recklessly wasted through ignorance of the laws of construction, and the confidence of the public in the profession is thus diminished.

For instance, one city engineer reports that sewers as large as 48 x 68 inches, with only a single ring of brick (4 inches), have proved perfectly stable, while in another city a sewer 24 x 36 inches, with a double ring of brick (8 inches), is adopted as a standard design. To design work so that it will be adapted to meet the different physical and financial conditions existing in the several municipalities, is an important and interesting study for the city engineer's office. The design suitable in one city may be entirely out of place in another, and it requires a thorough understanding of the premises and a good judgment to design in accordance with the requirements of each. Comparing two Massachusetts cities of the fourth class, as classified in Mr. Noyes' paper, we find the cost of granite block paving in one city to be $1.75 and in the other $3.50 per square yard, and to the average committeeman one pavement is as good as the other.

The city engineer's office will secure the respect of the public by using its influence to prevent excessive cost of constructing and maintenance of public works. It should be the aim in every city to pay fair and reasonable prices for all work. In many cities work is done by day labor and men are employed at a fixed price per day, without regard to their ability, and solely on account of their political influence. A city engineer, who has kept careful records in the matter, informed me that by adherence to this pernicious system his city is made to pay, on an average, 35 per cent. more than what would be a fair price for building its sewers on account of this custom. In a certain city, a double team, working by day labor, transported not over eight tons of cracked stone per day, but by contract work the same team with the same haul transported not less than twenty tons per day. It is the province of the city engineer's office to be so thoroughly informed in regard to the cost of construction as to be able to discover the existence of these practices and to apply the proper remedy, or, if they are beyond its control, to call the attention of the government to them.

Many of the difficulties of the city engineer's office arise from its relations with the committees and officers of the city government. Under our form of government, as it exists at present in most of our cities and towns, the force of the engineer's office is constantly changing. New men are, each year, voted into office by the people, and are charged with the expenditure of large sums of money to be used in the construction and management of public works. The city engineer hardly has time to become acquainted with the members of a committee, and to come to a thorough understanding with them, before they are replaced

by another set of men without previous experience, and to these he must again explain the condition and requirements of the public works. Many a time has the city engineer gone out from these committee meetings, thoroughly discouraged and disheartened, because his carefully designed and well-matured plans have been set aside by men without experience, men who have neither the capacity nor the desire to understand his plans, or the facts and explanations given. It is entirely probable that this method of government, one of the greatest obstacles to the economic and systematic construction and maintenance of public works, will continue in most of our smaller municipalities for years.

In dealing with committees or with boards, the engineer needs tact, good judgment, and plenty of patience. He must make free use of the facts obtained in regard to the present condition of the public works and of those gathered from the experience of other cities that have successfully solved the same problems, and he must constantly seek to impress upon the committees and others the importance of adopting the best methods in the management and execution of the work. The majority of men making up committees and boards are honest and intelligent, and the writer's experience is, that time devoted to a patient and careful explanation of the problem to be solved, the difficulties to be encountered, and the results to be obtained, will finally be rewarded by their co-operation with the engineer's department.

The selection of assistants and the organization of the working force of the office are among the most important parts of the engineer's duty. To properly organize the force, and to so place the different men as to command the best work, as well as to create and preserve in the force an interest in and loyalty to the cause, is absolutely necessary. The offices now doing the best work owe their success to such organization and to the combined work of the several departments, rather than to the special engineering ability of any one man. Better work will be obtained, even in the smaller offices, if the assistants are assigned to separate branches of the work, for each will then take an interest in his particular branch and will investigate all matters relating to it. If responsibility is placed upon them, it will materially increase their interest, and they will become much more useful to the office than if continually employed in mere drudgery. It is all-important that the assistants, who constitute the working force, should work in harmony, and, with a single aim, to build up and extend the influence of the office. Any one who cannot work in this line, or who causes dissatisfaction, should be called upon to resign. It sometimes happens that one man, who is not loyal, or who fails to take an interest in his work, may exert an injurious effect upon a whole office.

Mr. W. E. McClintock.—The average city engineer labors under this difficulty, that he is not accorded the privilege of taking the floor, and explaining his ideas, or refuting those of others. If he is in good standing with the Board, and if he has no enemy there, he may, perhaps, be called upon to explain his statements to the city fathers, but they are apt to resent any disposition on his part to instruct them as to what their duties are.

The city engineer should be allowed a seat in the Board room, in order that he may have the opportunity to explain his plans, and to defend them against misstatement and misrepresentation. He should have a voice, though he need not be allowed a vote. From the nature of the case, a city engineer must be something of a politician, but there is no reason why his politics may not be of the good and clean sort.

Mr. F. P. Stearns.—Quite nearly the practice which Mr. McClintock refers to, has been carried out in Worcester. I called on Mr. Allen one day when the city government met, and he invited me to go with him to the session to be held that evening. He had a regular seat assigned him in the meeting-room of the Board of Aldermen, and, although he did not speak unless requested to do so, he had occasion to speak several times during the meeting, expressing his views upon the subjects under consideration; and, as a rule, the action taken was in accordance with his views.

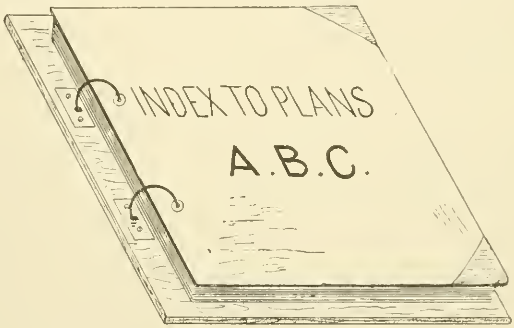
Mr. Lewis M. Hastings.—An important factor in the successful administration of a city engineer's office is, undoubtedly, a convenient and thorough system of classifying and indexing the notes, plans and data, which so rapidly accumulate. Nothing is more vexatious, and nothing indicates more surely the lack of business system, than a poor and inadequate method of indexing. Data, plans or information, which can not be *found when wanted*, are but little better than lost, and the engineer who has devised and prepared a ready and convenient index of information in the office, has performed a real public service.

In the Cambridge office it has for some years been the practice to classify the field notes under three general heads for indexing. The entry in the index is made almost immediately under the name of the street on or near which the work was done, and each street has three spaces left for the three divisions or classes of work, viz.: "Lines," "Levels" and "Surveys." Thus, the entries under Harvard Street will be as follows: "Harvard Street, Lines," "Harvard Street, Levels," and "Harvard Street, Surveys." This plan has worked very well. The index itself is an important item in the matter. An index in book form is quickly outgrown, unless made in a volume so large as

to be unwieldy; and the ordinary card index is still less easily carried about.

To overcome the defects of these two plans and to continue as far as possible the good points of each, I have had prepared an index, represented in the following cut:

It is in the form of a book or volume, of which as many as are needed may be used for the alphabet. The sheets of this book are easily taken out, and additioual notes may be entered on them, or additional leaves inserted as required. The index matter is preferably type-written on these sheets which are of stout paper. The back cover of the volume is of cherry wood, varnished; the front is of cardboard covered with canvas. The front cover and the sheets are attached to the back by two brass wire loops, one end of each of which passes through the back board



and is firmly fastened to it, the other end of the brass wire, passing through the holes punched in the sheets and in the front cover, are sprung back and locked in brass plates on the front of the back board. The sheets and the front cover run on the wire loops, and may be opened and thrown back like those of an ordinary book. By unlocking the lower end of the wire, the cover and any number of sheets may be removed, additions made, new sheets inserted in their proper places, and all put back as before. The volumes making the set are kept in a rack from which any one or all may be taken and carried to an adjoining room for consultation if desired.

The cost of the board back, front cover, lettering, etc., complete, was $1.18½ each. The paper for the leaves, ruled, lettered and punched, cost $1.50 per hundred sheets. This form of index has proved very convenient and serviceable.

Mr. Otis F. Clapp (by letter).—The system of indexing plans in the City Engineer's Office, Providence, R. I., is as follows:

Every plan, as soon as it is made, or, if its preparation is to take

long, as soon as it is begun, is entered in a day book, in which the lines are numbered from 01 up. These day book numbers represent the total number of plans made in the office, of whatever kind, for whatever purpose, or by whatever department. The numbers are printed on the left hand side of the book. On the right the two pages are ruled in columns with the following headings: Drawer and sheet number; title; made for; date; scale; kind of paper; size of sheet; field book and page; computation book and page; office number; field work by; platted by; drawn or copied by; recopied by; remarks. The last-named column usually gives the day-book number of the plan copied from. Care is taken to have the first word of the description the most prominent word of the title, as the name of the street of which the plan forms a part, or the name by which the plan will be most easily recognized or thought of when wanted. Then follows a short and comprehensive description of what the plan represents, stating whether it is prepared for office use, or for what committee or purpose.

The assistant who indexes the plan, having first determined in what drawer it should be placed, gets from the engineer's clerk the "office number," which represents the number of plans actually on file in the office, regardless of departments, and also the last sheet number for the drawer in which he intends to file the plan. For this purpose the clerk keeps two books, one, called the "Index Drawer Number" book, containing the *sheet number* and *office number;* the other, called the "Index Office Number" book, containing the *office number, drawer number, sheet number* and *day book number* for each plan indexed, placed in the order of office numbers.

The clerk's duty is to keep the work posted up to date. If he does so, he can tell the last office or sheet number used in every drawer in the office, and thus prevent the duplicating of numbers, which might happen if the last plan previously indexed should be missing from its place.

Having obtained the day book, office, drawer and sheet numbers, he proceeds to stamp the plan. Each department has what is called a "Department Stamp," and the clerk has one called the "Miscellaneous Department Stamp."

These stamps read: Providence, R. I., City Engineer's Office, ... Department, and each has a line for the date and one for the day book number. This stamp is placed at the upper right hand corner of the sheet.

Another stamp, called the Office Stamp, and containing the office number, drawer number and sheet number, is placed at the right hand lower corner of the sheet so as to be easily seen on opening a drawer.

The plan is next indexed in the "Department Index," each depart-

ment having an index for its own plans, giving the day book, drawer and sheet numbers, the title or name as entered in the day book, the kind of paper and the office number.

The Engineer's clerk posts the entries from the day book into a "General Index" under the name used in the day book (a street name, if possible), thus collecting together information concerning the location, etc., of all plans made for whatever purpose on that street or under that name.

On the first day of January, 1894, 022,032 day book numbers had been used, while on the same date the last office number used was 11,084. The difference of 10,948 represents the number of plans, copies, tracings or sketches made for committees or for construction, worn out or lost, etc., etc.

When a plan on file in the office is wanted outside of the office, the party taking it must sign a receipt for it, and this receipt is given up when the plan is returned. A record is also kept of such plans as are furnished and are not expected to be returned.

Mr. Henry D. Woods.—The question of indexing is a very vital one in a City Engineer's office. No matter how much material or how many plans there may be in the office, unless they are well classified and indexed, the amount of time lost in looking up any matter that may be wanted (usually on short notice) is very great, and it sometimes involves less labor to go out on the ground for the information than to look for it in a mass of plans not thoroughly classified. A good classification and a clear index are a great boon, but in order to keep them up to date, and to have them available, it is necessary to have some orderly and systematic person in the office to look after them, and to see that plans are returned to their proper place at the end of the day. Whenever possible, one assistant should be especially assigned to this work of putting up books and plans. What is everybody's business is nobody's business; and if, at the end of the day, each assistant undertakes, in the hurry of the closing hour, to put away the books or plans he has been using, they are apt to be misplaced and to suffer from rough handling. It is, however, no easy matter to find persons who are available for general office work, and who have, at the same time, the faculty for looking after this matter and of remembering where each book and plan is kept. The index, when kept by a person available for this work, gains its full value.

The method of indexing should be such that by a complete system of cross-references a note or plan can be found under any possible head, such as the name of a street, district, owner of lot, or surveyor. I do not profess to have been able to install any such complete method in the

City Engineer's office of Newton. In fact, it frequently happens in our office that there is difficulty in knowing under just what head to look for a matter. In the Newton office no attempt has been made to prepare a card index of notes. All note books are indexed at the end or at the front of the book, and when, owing to bad weather or other cause, there is a lull in the outside work, one of the assistants classifies in a rough index book all the notes obtained since the last classification. In winter, this rough index is transferred into a specially ruled index book and the notes are classified under each street, and for each division of the work; that is, the regular survey and level notes are written in black, the water-works notes in blue, and the sewer notes in red ink. The headings of the columns are Surveys, Staking-out, Levels, Levels for Grade, Setting Bounds, Concrete and Curbing, and Miscellaneous. Each note book is numbered as soon as it is started, and on the edge of the pages is marked what it contains, as: "Levels," "Surveys," etc.

Plans are numbered consecutively as soon as the base lines are plotted and the notes are plotted in part. Each plan is then entered on a rough index or plan book, and a location is assigned to it, in a drawer or a case. This index gives the general character of each plan, as: "District Plan," "Sewer Plan," etc.; with an outline of the ground covered, the date, etc. Profiles also are indexed in the same way and are given numbers in their order with the plans. Index letters, *a*, *b*, *c*, placed after the number, indicate that the drawing is a profile. The letter *a* is used for profiles occupying one-third of the width of the profile paper, *b* for two-thirds, and *c* for full width. From time to time, as with the notes, the list of plans is transferred into a special book, ruled in columns, giving, under each street: Drawer, Number, Date, Ward, Surveyor, Where Obtained, Nature of Plan, whether on tracing or drawing paper, whether mounted, lithographed, etc., and description. The location of drawer is marked only in pencil, both in the book and on the plan, as this may be changed if new furniture for keeping the plans is obtained. Later on, each plan is gone over and a card index is made for each street shown on it. Each plan, therefore, is referred to by as many cards as there are streets or brooks, etc., on it; but each card may refer to several plans covering the same territory. In order to facilitate the examination of the cards they are made of different colors designating different class of plans. If I am not mistaken, these colors and the general form of the cards was copied from those used in the Somerville office. The colors are: white for general office plans; yellow for land plans (plans obtained from outside parties, not made in the office); brown for public property plans; blue for water works; purple for drains and sewers; and pink for profiles. Each card is ruled in columns, in which are given: The number and location of the

plan, its description, and the name of the surveyor. In many offices other items of information are given on the cards, and this is frequently of considerable advantage. The cards are set alphabetically in the drawers, and each street is sectioned off by ward lines or by principal sections, so as to facilitate finding the special part of a street required. All plans are thus indexed, except committee tracings and the like, which are duplicates of the regular plans. They are simply indexed in one drawer where they are kept.

It is always best to keep the plans flat. Unfortunately it is rarely possible to do this, except with comparatively small plans. Deficiency of storage room and of convenience for handling generally render it necessary to roll large plans. These soon become checked, and their edges ragged, so that the life of the plan is much shortened.

For roll plans of large dimension, such as 62-inch Leonine, mounted, I find the most convenient storage is on racks formed of two parallel rods about 3 feet apart. If hard wood spools, 4 or 5 inches long by $1\frac{3}{4}$ to 2 inches in diameter, are strung on the rods, the plans will roll across them instead of scraping, and the damage will be reduced. For shorter rolls, diamond-shaped cases seem the best; but if more than seven or eight plans should be put in one case, they are difficult to get at quickly. The cases should also be proportioned to the sizes of the rolls; for rolls up to 2 inches, the cases should be about 6 inches on a side; and 12 inches for rolls up to, say 5 inches.

For long tracings I find that the most convenient method is to mount them on plan-rolls. These are split sticks, 1 inch in diameter, bradded together to the end of the plan, and further secured by means of a rubber ring at each end (as sold by Soltmann, of New York). The plan is rolled around the stick, making a solid roll, which is perfectly stiff and which can be handled without wrinkling the tracing. If the tracing is to be very much used it is a good plan to put a roll at each end; the second one need only be temporary and the rubber rings are sufficient to hold it.

For flat plans, shallow trays are the best; the shallower the better, for the natural tendency is to crowd into each tray as many plans as possible, and deep trays are thus made to hold too many.

At Newton we first used drawers $2\frac{1}{2}$ inches deep inside, or 3 inches outside, making four drawers per foot in height of case. We soon found these too deep for convenient reference to the plans, and, the large number of plans put in each drawer, made the drawers heavy. We now use only 1 inch deep. This gives eight trays to the foot; and each tray receives but fifteen plans. Possibly twelve trays to the foot, holding 10 plans each, might be more convenient in locating the plans if

numbered consecutively*; but the additional convenience would not warrant the increase in the cost, and the minimum thickness of the bottom exceeds the thickness of five plans, so that no more plans could be stored in the same space. In order to have the trays light and easily cleaned I had them made as follows: The tray is a hardwood frame of ½ x 2 inch stuff, and into this frame is fitted wire netting similar to that used in window screens. The tray slides in grooves prepared in the sides of the case. In order to keep the plans even and to prevent them from rubbing on the sides of the case, ½ x 1 sides and back are fitted to the tray, and the rear 4 inches of the back are covered by thin wood. The drawer has no front, and the plans can thus be slipped in or out. Each tray is covered with a sheet of wrapping paper to prevent soiling of the plans by rust from the netting. On top of the plans is a sheet of press board, on the front of which are marked in large figures the numbers of the plans belonging in the tray, and the plans are slipped in under this board, which prevents any plan from sliding over the foot board. There are 24 trays in each case, and the case is closed by a front which rises and slides back under the top and out of the way, giving access to the trays. By leaving the front projecting a little way it forms a convenient shelf on which to examine plans. The length of the trays from front to back is immaterial; it depends upon the available space, and upon the sizes of the plans; but owing to the tendency to sag under the weight of the plans there is a limit to the width. I have a few trays 52 inches wide, but this is excessive. The bottom of each tray strikes the rear of the next one below. I find that 36 to 40 inches is about the limit of width unless the trays are made of thicker stock, which of course occupies more room. I see no reason why the height of a case of this kind may not be made as great as desired. The vertical divisions that support the trays are fixed only at top and bottom, but the trays, when in place, prevent them moving laterally, and only a few are liable to be run out at one time, and then only for a fraction of their length. These partitions and the sides of the case need a little consideration. If solid panels are used, any shrinkage or swelling of the wood must affect the sides, for the strips on which the trays slide are made fast to the panels. These panels should be made up of independent pieces, say 4 or 6 inches wide, with spaces between them, and the slide strips should be fastened to them by only one screw to each piece. The shrinkage on each side of the screw will then not affect the slide. I have seen the whole woodwork of a safe thrown outward by this working of the panels to which the slides were made fast.

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* In our office the consecutive numbering does not take account of the size of the plans, whether flat, or rolled, or a profile.

For tracings that can remain flat, such as land plans, registrary tracings, etc., I find the most convenient way is to bind them in press-board covers, with a cloth back; these are easily made as they are needed by the boys in the office on rainy days. The plans may be bound together on cloth, with wire staples, and then glued to the covers, or, if required to be removable, they can be inserted in the covers with McGill fasteners, a lip being left on the covers and turned in. The numbers of the plans contained in each cover are marked on the inside of the cover at each end; and the book number and location is marked on the outside at each corner of both sides.

In French engineers' offices much more use is made of strong and tough transparent tracing paper. Usually this paper is wetted and stretched on the table over the plan to be traced, and fastened to the table with lip glue. If to be very much used, it is then mounted on a sheet of plain white mounted paper. The mounted paper is made in Germany and sold in rolls, all prepared, with a gummed surface which needs only to be dampened, and the tracing smoothed over it and is then practically the same as a mounted paper plan. The tracing paper is less expensive than tracing cloth; it is more easy to work on; it takes colors better, and when mounted it is opaque, and therefore easier to read from. I think but little use is there made of the less transparent white tracing papers (bond paper, etc.) such as are used here.

Long profiles must of course be kept rolled. If much used they should be on mounted paper. In Newton these rolls are kept in shallow cardboard trays or drawers, about 3 inches deep, 10 inches wide and 24 inches long, so as to take the full width of regular profile paper. Each tray will hold five rolls of full width, or five rolls of two-thirds and five of one-third width, or fifteen rolls of one-third width, or a combination of these, but no more. Each drawer has its number and letter corresponding to the case.

All the plans at Newton are numbered at each of the four corners. Tracings are numbered on the face, and other drawings on the back. All plans made in the office are marked at the lower corners with the note books and pages of the notes from which they are plotted. On district plans, if fully carried out, this might require an index to a majority of the books in the office.

Committee tracings and the like, which are only copies of office plans or sections of plans, and which are not valuable as records, have always seemed difficult to index and store. They are of all sizes and lengths. If rolled, unless put in the diamond-shaped cases, they should be in drawers similar to those used for profiles and sliding in cases having a clear smooth surface over the top of each tray. Otherwise the rolls are sure to catch on the drawer above.

Mr. Edward P. Adams.—When I entered upon my duties at the Lighthouse Engineer's Office of the First and Second Districts, in the fall of 1885, there were in the office several hundred plans, not only of surveys but of buildings and machinery, of fog signal and illuminating apparatus, on nearly as many sizes of paper, without catalogue or arrangement. Even the deeds to lighthouse sites were simply tied in bundles and placed in the safe in two pasteboard boxes, one for each district.

The inconvenience of this state of affairs, especially in regard to the deeds, at once attracted my attention, and I had two boxes of thin pine made, with hinged covers, to fit the largest pigeon holes in the safe, one for each district. In these the deeds and other title papers were arranged in the order of the stations on the coast, every four stations being separated from the next four, as is done in a card catalogue, by a zinc guide bent at the top to receive the printed names and numbers of the four light-stations that were cut from the blue book. When any title papers were removed from the box, a slip, containing the date of removal and the name of the person removing the papers, was put in the box in the place of the papers taken. This arrangement has worked admirably.

The work of arrangement of plans began with the older ones. These were placed in drawers, each of which contained the plans relating to four light stations in the order of the stations on the coast, commencing at the eastern of the two districts. But as thus arranged the small plans were hard to find, and were often pushed over the back of the drawer. To remedy this, in the arrangement of new plans and of those of the old ones which were still in use, I devised the following system:

All the recent plans in the office were divided, according to size, into nine classes. The standard sizes adopted for future plans were multiples of the size 5 by 11 inches, and each plan then in the office was classed with the nearest standard size. By means of a diagram, those plans were assorted, and the most useful sizes were selected and numbered. The size 5 by 11 inches was selected as the unit, because a great many blue prints had to be folded to that size in order to fit the official envelopes in which they were mailed to bidders.

The first size was 5 by 11 inches; the second, 10 by 11 inches; the third, 11 by 15 inches; the fourth, 11 by 20 inches; the fifth, 22 by 15 inches; the sixth, 22 by 20 inches; the seventh, 22 by 25 inches; the eighth, 22 by 30 inches; the ninth, 22 by 35 inches, and larger.

Three drawers in one plan-case were partitioned to receive these several sizes. The first drawer contained the first, second, third, fifth and seventh sizes; the second drawer the fourth, sixth and eighth sizes;

the third drawer the ninth alone. In these three drawers the originals and tracings were placed. Another set of three drawers contained the blue prints; and a third set, the duplicates. An original drawing, the tracing from it and the blue prints from the tracing, were all given the same number. The plans in each section of each drawer were arranged according to the numbers, increasing downward.

The scheme of numbering is as follows:

The thousands figure indicates the *character* of the plan.

0000—Old plans previous to 1885, except 7000.

1000—Surveys of lands and locations of lights on charts.

2000—Locations of buildings, and surveys of buildings after construction.

3000—Dwellings and out-buildings of wood, also details of wood except 7000.

4000—Light towers (except lanterns) and buildings of brick or stone, also details, except repairs.

5000—Lanterns and illuminating apparatus with revolving machinery.

6000—Fog signal machinery, engines, boilers and metal work repairs.

7000—Spindles and beacons, wharves and vessels, except 6000.

8000—Experimental apparatus and diagrams of experiments.

The hundreds figure indicates the *size* of the plan and its *section in the drawer.* In my own regulation surveys the tens indicate the light-house district; and in all the plans the tens and units figures indicate the order of time in which the drawings were made.

The degree mark (°) placed after the number in the catalogue, shows that the original is on file; the minute mark (′) that the tracing is filed; and the second mark (″), that there is a blue print in the drawer. In the catalogue also, a small "f," written under a number, indicates that the drawing is folded; a small "m" that the tracing or blue print has been modified; and a small "n" that the drawing is narrow, and therefore easily overlooked in the drawer. The small "m" is also placed on the tracing or blue print modified.

The plans are indexed alphabetically, according to the light stations represented by them, except that the General Service plans precede the alphabetical index. The date and subject, as well as the number, are given; and if a plan applies to several stations it is indexed under each. The first district plans are indexed on the right hand page, and the second district plans on the left hand page of the leaf.

Small number-record books show what numbers have been taken and therefore what the next number should be, and the general scheme of numbering is given also in each catalogue and number-record book.

To-day about 875 plans, not including about twice as many duplicates, are on file in our office, and any one of these can readily be found

at any time by reference to the catalogue, unless the plan has been removed from its place and not returned, as is the case when it is in use in the office or machine shop.

A card catalogue indexes the main results of the surveys and the numbers and dates in relation to them. Each note book has a table of contents with dates.

CITY SURVEYS.

By William E. McClintock.

The Surveyor and the Survey are as important to the Civil Engineer as are the formulæ and the logarithm tables: the "modulus" and the "moment."

If the Civil Engineer cannot spare the time to manipulate the transit and the level, he must send into the field others who will do this part of the work, and who can be trusted to do it accurately and economically.

The value of most estimates of stability, strength or cost of public works depends on the trustworthiness of the data used, and it is therefore incumbent upon the Engineer to study with care his methods of securing such data as may be needed.

The necessity of a thorough survey of any city or town is so apparent to the Civil Engineer that it seems almost a waste of effort to call attention to it, and yet in most cases the completed survey is as much a thing of the future as ever.

Street lines and Street grades: Sewerage systems, in part or complete: Water pipes and Edgestones: and assessment plans for various purposes, call for more or less perfect surveys and plans before work can be properly begun. Under the short-sighted policy of the past, disconnected surveys and plans have been furnished which would meet the immediate demands of some special improvement without reference to future work, so that in nearly every case where important work is proposed the surveys have to be made anew.

If the entire survey cannot be made at once it should be so planned that each isolated survey can be utilized as a part of the whole.

Probably the only method by which the disconnected surveys can be made a part of the completed survey is that which determines the co-ordinates of the survey points. These co-ordinates may be worked out from an assumed origin, or they may be referred to the U. S. Coast Survey System, which takes the meridian and the parallel as the axes and determines the latitude and the longitude of each point.

If the first method be used, a carefully selected base-line must be correctly measured, and from this the remaining points are to be determined by triangulation.

If the Coast Survey System is to be used, we may take any two or more points which have already been determined, and whose latitude, longitude and azimuth are given. The distance between two of these points serves as a base-line.

The main facts to bear in mind are that with the local base and the assumed origin the triangles are plane triangles, and that the azimuth and the back azimuth are supplements of each other.

If the Coast Survey System is to be used, it must be remembered that all meridians converge until they meet at the pole, a fact which necessitates a correction to be applied to the azimuth in order to find the back-azimuth, which is the angle at the pole subtended by the two points and which is measured by the difference in longitude taken on the mean latitude.

In the writer's opinion the latitude and longitude method is the better of the two, as by its use the work can readily be joined with that of adjacent towns so as to give one completed work.

In selecting the triangulation points, street or town bounds should be utilized as far as possible. Where these bounds can not be directly determined they will have to be connected with the scheme by a carefully run traverse line, a matter to which reference will be made further on in this paper. Fortunately in the towns and cities of Massachusetts a sufficient number of triangulation points for a survey are available. These points have been carefully determined by competent triangulators employed by the State Topographical Commissioners, and their positions can easily be obtained on application to the Commissioners.

It is not my intention to describe in detail the latitude and longitude, method for such description can be found in a paper prepared by the writer, read beforé this Society in June, 1882, and published in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, Vol. I, page 290.

It is well to bear in mind that by a judicious use of the points already determined, enough new points can be observed and computed to make it a simple matter to connect any street survey with the co-ordinate scheme. The new triangulation points may be such as can readily be seen from the points already determined, or they may be street bounds, corners of brick or stone buildings, or other stable structures. The base, being furnished by the State triangulation, need not be criticised or checked. Most of these points are carefully and securely marked by stone monuments. All the new points should be marked in an equally careful manner, bearing in mind that the frost is no respecter of the surveyor's rights.

The writer thinks that a monument should be of stone, not less than five feet long, and should have a top six inches square, cut down on all

four sides to allow of paving around the monument. These monuments should be set in the ground as nearly plumb as possible, and the dirt should be carefully filled in around them and thoroughly tamped in thin layers. All street bounds should be of the same dimensions and should be set with the same care.

A street bound, if set on the street line, is liable to be displaced during the construction of buildings or fences, while a monument located in the middle of the street is sure to be removed during the laying of car tracks or the digging of trenches for pipes. It is difficult to set the transit over a point in either of these lines, and considerable time will be lost in making offsets and determining intersections.

In the writer's experience a street bound, set on a three-foot offset, is reasonably safe from being disturbed; the instrument can be readily set over it, the line of sight is fairly free from obstruction, and the offsets to the true line are small and easily made by one assistant.

The tops of all street bounds ought to be set carefully to the sidewalk grade, allowing the proper pitch from the curbstone. A book should be kept that will show the location of each monument by a sketch with tie measurements, so that the location may be easily determined, even though the monument be covered with snow and ice. Many of the street bounds may be determined by direct triangulation, and the rest will have to be connected to the scheme by traverse lines. This can readily be done by setting over a triangulation point, measuring the angle between a line to a second triangulation point, and the first line of the traverse; and running the traverse line to include one or more sets of monuments, ending it at a triangulation point where the angle between the traverse line and a line to the triangulation point will be observed.

By this method the azimuth and the co-ordinates of the traverse line will all be checked. It must be remembered that the best of instruments for measuring angles are more or less defective, in the telescope, in the crosshairs, in the centres, in the graduation, and in the head. Any unequal expansion or contraction of the instrument magnifies natural defects. It is therefore important to eliminate such errors, as far as possible, by careful adjustments of axis, cross-wires and levels; by preventing the direct rays of the sun from falling on the instrument, and by a number of repetitions of angular measurements sufficient to insure the required degree of accuracy. If the points be but short distances apart, twelve repetitions will give reasonably good results, and as the sides of the triangles lengthen the number of repetitions can be increased up to twenty-four, or even to one hundred or two hundred.

In making these observations it is well to use the greatest care in clamping and unclamping the vernier or limb, and to read the first angle as a check.

Sets of six angles are recommended, as the notes are then more easily kept up; the remainder, after dividing any denomination by six, constituting the tens in the next lower denomination.

Equal care must be used in all measurements of the traverse line. A steady pull of say eight pounds on a steel tape and a reduction to the standard temperature are essential features if close agreements are desired. The writer thinks that the most accurate measurements can be made by setting tacks or nails on a carefully sighted line, at distances not so far apart as to prevent the free use of the plumb. If enough triangulation points are determined, each survey can easily be connected with them, and each point in the survey becomes determined with reference to the origin of co-ordinates.

The next step is to construct a plan on which each survey may be plotted to the scale best adapted to present and future requirements. It is good practice to make this projection on sheets which can easily be handled and used on a plane-table if desired. The writer has found an antiquarian (30 x 52 inches) sheet well adapted to both office and field purposes. Draw the centre meridian and "parallel," and on these scale off the squares most convenient to use. These may be five seconds or more, depending on the scale, and bearing in mind that the squares are more easily used when not more than three or four inches on a side. The lines should be very fine and very carefully drawn, and the value of each line should be marked at the edge of the sheet. On the projections thus prepared, the triangulation points can be plotted. The local surveys can be readily plotted on the sheet, as each point in the traverse line is already shown.

In the case of large sections of country not much built upon, the stadia or the plane-table can be used to great advantage. By either of these methods the plan can be completed and all local objects shown thereon.

In order to make a proper study of a proposed water or sewerage system, the levels should be shown on the plan. These can best be indicated by contour lines showing planes of equal elevation, say from two to five feet apart. In many cases these can be plotted from notes already on hand.

In the manner already described, a complete survey and map may be had with a comparatively small amount of extra work.

One of the vexing features of a city engineer's work is the giving of lines and grades of streets. Many of the original surveys are often found to be defective; most of the few bounds which were set are gone and the perplexing problem of what to do with the surplus which is often found, stares the engineer in the face. When the streets are abutted upon by unimproved land, the surplus may be distributed

equally, but it more often happens that buildings have been erected along the street, and careful measurement and the exercise of good judgment are then required.

In many cases the structure must be taken as fixing the street line, and a fairly straight line may sometimes be found without much loss in width of location.

The determination of grades is even more difficult. Many of the older towns had no engineer, and each owner built to any grade which best suited his fancy. Local statesmen have hesitated to sanction a grade which would cause injury, real or fancied, to their constituents. The result is that very often no system of grades exists. Surface drainage is not provided for, one curbstone is set at a different level from the one opposite it, and the street intersections are left to take care of themselves. The only method to be pursued in such cases is to make careful levels of the centre and sides, and to adjust a grade which shall injure the abutting property as little as possible. In many cases, deviations may be made from straight grades, and a little difference of level between the two sides of the street is permissible. This difference should in no case exceed the established crown of the street, for, if it does, the slope will be uncomfortable, if not dangerous to teams.

One important object of a good survey is to obtain the data for designing a system of sewerage. A profile of each street is needed for such a study. This can be made on the ordinary continuous profile paper, on a scale of 100 or 200 feet horizontal and 10 or 20 feet vertical. The measurements may be continuous and the levels may be taken at points 100 feet apart. All culverts and cross streets should be shown, and their positions figured. A study of the contour plan will show the possible outlets, and the profiles will make it possible to work out the best routes, the depths of the trenches, and the estimated cost.

The final drawing shows both the plan and the profile, one above the other, and on these may be indicated all buildings and manholes, the surface of the ground, the line of the sewer and of branches of all kinds. The branches may be located by measurements from each manhole, and the house connections by measurements from the sides of the buildings.

In making these plans, it is well to use a uniform scale and sheet. An imperial sheet makes a convenient size on which to work, and it can be bound up with about fifty sheets to a book. Paper is cheaper than time, and it is well to have all plans on sheets of uniform size for convenience of filing away.

The engineers of the smaller cities are generally paid but small salaries, and their duties during a part of the year are very exacting. During the remainder of the year, they have more or less time at their

disposal, and they naturally feel that they have already earned what little salary they are paid, and that they need not trouble their minds about starting any work which is not demanded of them. The city engineer who allows his mind to stop working during a part of the year, because his renumeration is not what he thinks it should be, may continue to hold his position for a short time and be fairly successful, but he is not the man who will be selected from a crowd to fill a higher position. If the office is small, it is the engineer's duty and opportunity to build it up, and bring it into prominence.

A carefully executed survey, or the design of a sewer system, is sure to cause extra work and to make a busy season of what would otherwise be a period of rest, but it will give him valuable experience, and it may be the means of raising the engineer to a higher professional plane.

Mr. Fred. Brooks.—I heartily approve of the recommendation of the last speaker, that *upon municipal maps and plans there be drawn a set of north and south, and east and west lines.* This is one of three points of practice, the importance of which I would like, briefly, to emphasize, because, in spite of their being well-known matters, they are too often neglected. One distinction between municipal and other work is, that municipal work is limited in territory. Even if the preparation of a complete map is not undertaken at the outset, surveys are likely, in time, to cover a large proportion of the territory of a municipality, and it is comparatively easy to connect the different parts of the wcrk, and to conduct it systematically, as can hardly be done if the work is in widely separated places. Like the lines of latitude and longitude on maps of larger portions of the earth's surface, a set of squares on municipal plans is of advantage in facilitating the understanding of the plans in copying, enlarging, or reducing them, in comparing, classifying, indexing, and connecting different sheets, and in projecting work. I have in mind particularly the use of a system of rectangular co-ordinates, parallel and perpendicular to some meridian taken as a standard. Within the small territory apt to be included in the plans of any one municipality, the convergence of other meridians is too slight to constitute an objection to such a rectangular system. Here, in Massachusetts, a great many stations and landmarks were located by the State Survey, half a century ago, and those in the eastern part of the State were tabulated by co-ordinates parallel and perpendicular to the meridian of the State House in Boston. At the present time, the State Topographical Survey is accurately locating trigonometrically all the municipal boundaries. Hence no municipal engineer can decently neglect to connect his surveys with the State map. The use of a calculated system of rect-

angular co-ordinates for surveys in general, was carefully explained and discussed in a paper by the late Henry F. Walling, a member of this Society, published in the *Transactions of the American Society of Civil Engineers*, Vol. VI, pp. 88–106 (February, 1877). Mr. Doane, Past-President of this Society, has conducted his surveys in Charlestown on a system of rectangular co-ordinates, as he explained to us at one of our meetings long ago. The idea is very well known. Squares have been drawn on the plans of railroads and water works, with which I have been connected. Although this practice has been, to a great extent, neglected in the Boston City Surveyor's office, the Board of Survey, recently organized, has adopted the system completely, as appears in its forthcoming report, dated February 1, 1894. It uses rectangular co-ordinates parallel and perpendicular to the State House meridian, and it has blocked its work out into squares of 1,000 feet on a side, containing 1,000,000 square feet, and squares of 10,000 feet on a side, containing 100,000,000 square feet. The co-ordinates of points are figured upon the plan, the scale being made large enough to admit of this.

The second point of practice, which I will treat at a little greater length, is, that *municipal land plans ought to be drawn to decimal scales.* The municipal engineer is so situated that he can adopt decimal scales before other people do, for his work is kept in one office where he can have things especially adapted for his purposes; whereas an engineer in general practice may have to carry on work in various places and with different assistants, and be less ready to make any variation from old-established customs. I may again cite the practice of the Board of Survey as in great part an example. That Board adopts, as the principal scales to which its plans are drawn, such scales as one thousandth of natural size, four one-thousandths, of natural size, five one hundred thousandths, and (for profiles) two hundredths, which can be expressed as decimal fractions. They are, in this respect, totally different from the scales that have been most commonly in use, but similar to some of the scales chiefly used by the U. S. Coast and Geodetic Survey, though the latter are generally smaller. If, in surveying land, we continued to use inches as well as feet, something might be said for the common scales; but the Gunter chain and link, decimally connected with the furlong and acre, long ago became exclusively "surveyor's measure," and tapes of 100 feet, divided into hundredths of a foot, have recently supplanted the Gunter chain in the United States. It is not in harmony with either system of decimalization, but is an antiquated idea, to adhere in the drafting of plans to the subdivision of the foot into twelfths.

Another example of the recent adoption of the practice recommended is in the case, not of land plans of a municipality, but of shop drawings of a manufacturing establishment. From the Turbine Foundry at

Brigg in England, Mr. Charles Louis Hett, Assoc. M. Inst. C. E., writes, June 14, 1893, to *London Engineering* that he has commenced using such scales as 1–5, 1–10, 1–25, 1–50 of full size, instead of 1–4, 1–12, 1–24, etc.

Decimal scales are adapted not merely to any ancient measure when decimalized, as for example to the British foot as now temporarily used here in surveying, but also to the metric system, which is evidently coming into universal use. This fact furnishes the reason for Mr. Hett's action, and, to my thinking, the best reason for such action in any case. In the case of the Board of Survey, the triangulation is based on Coast Survey work, which is in meters. (See the figures in meters on p. 57 of the Board's report.) Chief Engineer Ellis, of the Board of Survey, explains that the width of one's thumb nail on the map represents 1000 times the width of one's thumb nail on the ground. Then 1 inch of map represents 1000 inches on the ground, 1 foot of map 1000 feet on the ground, 1 millimeter of map 1 meter on the ground, and 1 meter of map 1 kilometer on the ground. If a plan, made to-day upon a decimal scale, is preserved until after the exclusive adoption of the metric system, distances in meters can be conveniently read from it by metric scales, whereas a plan made with old-fashioned inch-derived scales will be found particularly inconvenient for scale measurements by the metric system. New information in meters can readily be added to an old plan, if its scale is decimal, though the original surveys may have been in feet. This subject was fully and clearly presented to the Society on March 3, 1886, by the Committee on Weights and Measures, then consisting of Messrs. Swan, Folsom and Kettell. (See Vol. V of the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, pp. 270–2.) I have used decimal scales for various plans made in feet, and particularly on some railroad plans for record, which are likely to be preserved for a long time. The importance of this practice is increasing with the increasing use of the metric system. About this progress our Committee on Weights and Measures informs us from time to time. In the report of the Committee on the Metric System of Weights and Measures, presented Feb. 16, 1881, are the following passages (see p. 118, of the printed records of the Boston Society of Civil Engineers) referring to changes visible in the publications of our younger sister, the American Society of Civil Engineers:

"During 1880, besides the discussion of interoceanic canal projects, considerable of which was in metric measures, there were published three other papers that were either written in the metric system or with duplicate metric and old values; . . . .

"Previously to 1880 the use of the metric system in that society's *Transactions* consisted of a few metric scales on the illustrations, and

some references in the text where the metric were evidently subordinate to the old measures."

In the five numbers of the *Transactions* last issued (for July–November, 1893), having nearly 1,200 pages, there are about fifty papers, very nearly half of which are in metric terms, and two-thirds of which contain some metric quantities or equivalents, or electric measures based on the metric system. Of the accompanying plates and diagrams there are about a hundred that have linear scales, and more than half of these have metric linear scales.*

If to-day we come across a plan in rods and links, we regard it as of inferior character, and plume ourselves upon not being as those other men were who did such old-fogy work ; yet it may have been made by some man of a former generation who did the best he knew. When the next generation shall look back upon many of the plans that we are making now, must it not characterize them as old-fogy productions, and add that we did not do the best we knew, but, with abundant opportunity to foresee what would be wanted, shut our eyes firmly and blundered along in an old rut?

The third point of practice to be insisted upon is that *the plane of reference for leveling shall be the mean level of the sea.* While this, like the other two things, is good policy on any surveys, it is upon municipal work that it is most easily adhered to. This also has been discussed before the Society. It was referred to a committee consisting of Messrs. Thomas Doane, Thomas W. Davis, and Joseph H. Curtis, who reported squarely in favor of referring elevations to the mean sea level. The report was made April 20, 1881, and, with discussion by Henry Mitchell, who gave information as to the observations necessary to determine mean sea level, was printed on pages 135–7 of the records of the Boston Society of Civil Engineers, and on pages 20–22 of Vol. III of the "Proceedings of the American Metrological Society."

Shunk's *Field Engineer* expresses the same principle very simply in the following language (from page 26):

"Suppose *A* * * * the initial benchmark. Wherever convenient the elevation of *A* above mean tide should be ascertained. It is to be regretted that this was not done from the outset, under statute provisions requiring maps and profiles also to be filed at the several State capitals. In that case, not only would much after-labor and expense, by way of duplicate surveys, have been spared, but the older commonwealths

* The Bulletin (No. 41) of the American Society of Civil Engineers, May 11, 1894, contains the rules recently adopted by the Board of Direction, to govern the preparation of illustrations to accompany papers presented to that Society. Rule IV says: "Scales must in all cases be drawn upon the original and show both English and metrical units."

would now have in hand materials for the preparation of physiographical maps, the value of which to science, to the engineer, and to the economical geologist, it were hard to measure."

I used this base on plans for Wakefield sewerage in 1889. This city of Boston still furnishes an awful example of what ought not to be done, having incongruous bases for levels in use on different parts of its work, one being substantially low water mark and the other substantially high water mark. That this folly will be kept up forever is not to be expected unless we despair of the progress of the human race. To change to one reasonable and permanent base would be easier now than in the future after more figures shall have been made. Happily for this community's reputation for intelligence, the State topographical survey uses mean sea level as the plane of reference for its contour elevations. Last season it had a line of precise leveling carried across the State, starting from a connection with tide-water at the Charlestown Navy Yard, where a very long series of observations of the sea-level has been made. This was previously available to fix a base for Boston and adjacent cities; now it is available more conveniently than before for municipalities in the interior of the State; for at railroad stations or elsewhere along the line of the leveling, the State surveyors have established reference points marked with the elevations above the mean level of the sea. It is within the province of such organizations as this Society to incite all concerned to take advantage of this opportunity and secure the benefits of accuracy in measure ment and of uniformity in practice.

SURVEY OF THE CITY OF LOWELL FOR ASSESSORS' MAPS.

By George A. Nelson.

Early in 1886 the Lowell City Council voted to appropriate $5,000 from the reserve fund to begin a survey of the city for assessors' maps, and in August a party from the City Engineer's Office started on the triangulation.

A base line was laid out in the western part of the city along a level tract of land now used for a boulevard, and stone bounds were set at the ends. The distance between these bounds was carefully measured upon stakes, set at intervals of fifty feet, upon which levels had been taken. The length of this base, corrected for levels and temperature, was 3,413.65 feet. Favorable points were selected in such positions that a series of four quadrilaterals extend across the city from west to east. The shortest line in this part of the work was 2,098.40 feet, and the longest line 14,572.12 feet. From these occupied stations a set of secondary stations were located, forming in all fifteen occupied stations.

The positions of thirteen unoccupied stations were established upon well-defined points on prominent buildings, favorably located throughout the city. This work was done with great care. The angles were taken by making a series of observations consisting of six readings direct, and six readings reversed, upon each quadrant of the theodolite, no error greater than three seconds being allowed to enter. The meridian was taken from the greatest eastern elongation of polaris upon Fort Hill station, the latitude and longitude of which had previously been established by Mr. E. W. F. Natter for the State Survey, also by Prof. Quimby for the State boundary line survey. On account of the slight convergence of the meridians within the city limits, it was decided to confine the calculations to strictly rectangular co-ordinates, instead of using the geodetic formulas. The city was divided into rectangles, with sides equivalent to twelve seconds of latitude and twelve seconds of longitude, or 1,214.78 feet and 897.01 feet respectively.

From the first it was decided to make an actual survey of each lot, including the buildings. This work has been done by running, as far as practicable, traverse lines parallel to the established street lines, and locating the street lines and property lines from these bases, seldom using the transit for locating division lines, these being measured and located by the method of intersections. There have been over 1,200 angle stations established, forming over 500 traverses. Each station has been referred to the axes of co-ordinates, and the intersections of the traverse lines with these axes have been calculated, affording complete data for plotting all the work upon each individual sheet. The azimuths of the lines and co-ordinates of the stations have been checked with the triangulation. The average difference of the co-ordinates of eleven triangulation stations, as determined by the triangulation and by the traverse work, has been 0.18 of a foot north and south, and the same east and west. The azimuths of all lines have checked within one minute.

At first it was proposed to make the survey by fence lines, but it was soon found that the fences in a great many cases were not on the true lines, and often no fences or boundaries were in place; therefore, all the plans obtainable were copied, classified and indexed for reference. Assistants were also set at work copying from the registry into books of convenient size for reference while plotting the work, all deeds of property in the sections of the city to be surveyed.

To save time, deed sheets, consisting of rough drafts of the deeds, have been compiled by these assistants for use in the field work and in compiling the maps. All points referred to in the deeds are carefully noted upon these deed sheets. They are very useful in helping to find

important boundary points, and they show by inspection the work to be done.

The rectangle, formed by the axes of co-ordinates for the single map sheets, was carefully laid out, once for all, upon a sheet of thick zinc, and very small holes were drilled at the points of intersection of these lines. This zinc templet is placed upon a sheet of Whatman's Imperial hot-pressed, mounted drawing paper, and the points of intersections pricked through. Lines are drawn through the needle points in the paper, and the sheet is then ready for plotting the notes covering that particular section of the city. Special care is taken to season the paper thoroughly by hanging it in a warm room for a couple of weeks, in order to overcome as much as possible the shrinkage and expansion. The scale used for the map work is 50 feet to the inch; each sheet is 22 inches by 29¾ inches, and covers about 25 acres. As the city includes twelve square miles, it will require about 300 sheets if all are drawn to this scale. The sheets are indexed by letters north and south, and by figures east and west.

The work of harmonizing the plans, deeds and surveys, and of drawing the maps, is done during the winter by the heads of parties, the assistants being employed in copying the deeds and any new plans, and in compiling deed sheets for the next season's work. All the buildings are plotted and colored yellow ochre for wood and brick-red for brick. The dimensions of the property lines used in estimating the areas are now put upon the maps. When possible, the areas are calculated directly from the dimensions, otherwise, by scaled diagonals and perpendiculars, or by planimeter. It is intended to keep the error in area within five feet in a thousand, and in valuable sections the exact area is obtained when the data will admit of it.

Instead of turning over the finished maps to the Assessors, tracings are made upon bond paper, omitting the buildings and giving the areas in ink, and the names of the owners in pencil, as these are constantly changing. These tracings are bound in folios, each including a certain division of the city. The assessors write with pencil upon the lots their assessed values per foot, as these valuations are subject to change, and estimate the valuation of the property from the areas given.

The work of surveying the city has been continued without interruption for seven years. During the first four years, two parties of three persons each were upon the survey; but during the greater part of the last three years only one party has been continually employed upon the work. About 3577 acres of the most valuable and thickly settled portions of the city have been surveyed at an average cost of $9.00 per acre. In the outlying districts, now to be surveyed, the lots are larger and there are fewer buildings; the cost of the remainder of the survey will therefore be very much less.

The maps have proved of great advantage to the Street, Sewer and Water Departments, and they are frequently referred to by other departments of the city government. The recent renumbering of the city has been based upon these maps, and in other ways they have been of great value to the city.

Mr. Edward W. Shedd.—The work in the city of New Bedford is directly in the line of what Mr. Nelson has given us, and the system which he has used there is nearly like what we are using in New Bedford at the present time.

At first we took a long straight street for our base, and began to run the transverses at certain distances off the street line, but we found that this method would create some difficulty, as it brought in many small angles. We therefore finally gave it up altogether and began in the centre of the street where we could get long sights and a clear coast.

We have decided to swing the whole survey into line with a true meridian, probably that of the High School. This meridian and the latitude of the High School, I understand, are very accurately determined.

We use sheets 26 inches by 39 inches, and plot all stations from the co-ordinates. The scale, 60 feet to the inch, is an awkward one. I greatly prefer 20, 40, 80 or 200. With these, any person, with a two-foot rule, can get a pretty intelligent idea of the distances. We started to measure the fences, but I believe that the Commission in charge of the work is somewhat undecided as to whether deeds or fences are the better. The Commissioners asked us to show the fence lines and the deed lines. We suggested that the deeds should be relied upon, unless they were evidently erroneous, in which case, of course, we should have to be guided more or less by the positions of fences or by priority of claim.

On the plans at the office we have drawn all the deed lines in blue, and when the lots are measured we draw them in black, and I think it safe to say that in a block of lots there are not more than one or two cases where these two lines exactly agree. I think it will be finally decided to use the fence lines showing the lines of occupancy, and then New Bedford will be a good place in which to open an office.

As a rule there seems to be more land than the deeds show. If a question is raised as to the correctness of the survey of a given lot, the assessors refer to the blue lines which appear on the office copy but not on the finished plans.

It is not intended to put the names of the owners upon the lots, as I understand was the case in Lowell.

Mr. Nelson.—In Lowell, we keep a record of the names of the owners of the lots, but these names are entered only on the tracings which we hand over to the assessors, and not on the plans.

Mr. Shedd.—In New Bedford the following system is proposed: The sheets will be numbered, and on each sheet the lots will be numbered. Books will be furnished in which the names of the owners of these lots, by sheets and lots, will be shown. The areas will be entered in the books and on the plans.

Many changes are constantly being made, and it will be very much easier to keep the business up to date if, as far as possible, the plans are simplified and the data entered in books.

The mounting of these plans will be different from anything I have seen yet. They are to be mounted on cardboard, 26 by 39 inches, and the paper used is Whatman's "Cold Pressed." This is put on by shellac, I think. The binding will be of brass. The sheets are all mounted on heavy cardboard and the backs are varnished. The scale used is 60. We are making an index plan to a scale of 400. There will be about 240 sheets. These will cover the entire city, and the scale will be uniform throughout. The scale may be changed later for the territory in the south part of the city where the holdings are large.

Mr. McClintock.—With our system of plans in Chelsea we had a good deal of the same experience as in New Bedford. We had a surplus of land, although the lots were fairly small.

When the question came up as to whether we should show the deed lines or the actual lines, we finally decided to show the actual occupancy. In lots where the surplus was only 6 or 8 inches, it made but very little difference to the assessors, but some of the lots were found to have a surplus as great as 12 feet in 250, and this, of course, had to be divided up in some way.

Cardboard seems to be one of the best materials obtainable. Ten years ago I mounted my maps on a half imperial size of heavy cardboard and bound them with tape, but the whole front and back of the plan were shellacked. We kept them in cases, standing on their ends, so that the index letter was in the upper left hand corner.

Each sheet was numbered and each lot was lettered. These were divided into groups marked A–1, A–2, A–3, etc., so that the subdivisions referred to the original division. To keep a record of deeds a portfolio was used showing the owner's name, the year, the page of registry, etc., where it was recorded, and twenty years ahead, was printed in the book so that the assessors would have no trouble in looking up the deed in any year. All points were geodetically determined.

Mr. H. B. Burley (by letter).—In cities having a population of over 18,000 or 20,000 persons, the Assessors cannot well perform their work without maps of some form by which they can ascertain conveniently the amount of land owned by any person, or ascertain the ownership of any particular tract of land. Especially is this true if the transfers are numerous, and if much land is subdivided into lots held on speculation. The advantage to Assessors in having complete property maps is evident. They are thereby enabled to know who are the owners of the land within the city, they can tax it all, and they can make their assessments with greater equity. The City Engineer of a small city, or one of moderate size, is then likely to have, as one of his duties, the management of surveys and of map work, the object of which is to complete plans which shall serve, to a greater or less extent, the purpose above noted, and which are commonly called assessors' maps.

City surveys, which include the location of all streets and property division lines, may be divided into three classes or grades:

First: The work under the first grade includes primary triangulation of the greatest practicable accuracy, and this may often be extended from points established by the United States geodetic surveys; also a secondary system of triangulation, in which all street lines are located by triangulation and described with reference to co-ordinates. It includes a very careful survey of all subdivisions of land and the thorough examination of their titles.

Plans made from surveys of this grade would, of course, serve to perfection—unnecessary perfection—the purposes of the Assessors. Such use would be secondary only, and these maps are not properly classed as assessors' maps; they are property maps, which may be used as an authorized record of land titles and transfers. They will be considered further in this paper.

Second: The second grade of map work includes all of the first as far as triangulation is concerned. Streets are located by triangulation and the property is surveyed with a good degree of accuracy. The matter of land ownership is not investigated as thoroughly as in the first case, for the plans are not intended to be used to any extent as a basis for the transfer of land. From such data maps for the assessors' and for the engineers' department may be made. The assessors' maps are usually drawn to a scale of 40 feet to an inch, on mounted paper in sheets of uniform size suitable for binding. It is common practice to show street lines, property lines, buildings, the dimensions and areas of lots, and the number of each lot. The name of the party owning each tract is recorded in an index book. The sheets may be indexed by an index map of the city, drawn to a scale of about 800 feet to an inch,

the sheets being numbered and grouped in districts and the maps tinted in different colors for each district.

As for the plans for the engineer's department, compiled from surveys of this class, the practice sometimes is to put the information on sheets 5 by 10 feet or larger, showing street locations, all properties and dimensions, and buildings. Again, they are frequently made on small sheets which can be bound together. They may show, also, curb lines and elevations. The leading feature, however, is the exact indication of the location of all streets as determined by the careful triangulation work.

A few of the large cities, among them St. Louis, Philadelphia and Boston, are adopting this system of completing accurate records of street lines. It is the only excellent system. By no other practicable method can the alignment of streets be accurately and definitely described, because there must be something that will remain for reference in the description of location.

It is, of course, expensive business to record the alignment of streets by reference of co-ordinates, but those who are familiar with surveying practice realize the importance of such a system. City surveyors should bring the matter to the attention of the City Councils in order that they may be induced to provide for such work.

Every city engineer knows what it is to re-run an old street line described by a compass bearing beginning at "stake and stones," etc. Nowadays, with good instruments at hand, no street description should be recorded, which, to the engineer of one hundred years hence, will appear so crude.

Third: In cities of 20,000 to 50,000 inhabitants there is often great difficulty in getting a sufficient appropriation for the engineer's department. The need of a good property map is felt by the City Engineer and by the Assessors, but it is hard to procure extra money to pay for such map work, and the Engineer has to be content to make attempts at odd times and in a small way. Occasionally, however, through the influence of the Assessors, the City Councils will set apart a sum for "Assessors' Maps." The surveyor in charge of the expenditure of that appropriation may not be at liberty to do other than compile, in the simplest and shortest way, plans of properties throughout the city, giving all the information required by the Assessors. The triangulation may have about one triangulation point to every 200 acres. The traverses connecting these points should be carefully run, and streets and property lines should be located with a good degree of care. The buildings may or may not be shown. The primary object is to provide assessors' maps, and what data or plans the engineer's department obtains from the work, will depend somewhat upon the ingenuity of the surveyor. In the first

and second classes the provision of assessors' maps is a secondary consideration, but in this, it is the main purpose.

As an instance of the completion of map work under this class, the writer would briefly outline the methods of carrying on surveys and of completing plans, adopted in the City of Nashua, N. H.

Nashua has a population of about 20,000. The area included in the survey is about 4,600 acres, of which about 2,000 acres is closely subdivided.

Two base lines of about 2,600 and 2,900 feet respectively were measured with a 300 foot steel tape. The surface of the ground over which the bases were measured, was not level. Some changes in tape level were necessary, and these were made by setting a transit 20 or 30 feet to one side at right angles to the line. Two measurements of each base were made. The difference in length in each case, by the two measurements, was about 0.00001 of the whole length.

The two base lines, one of which was on the east side of the city and the other on the west, were connected by triangulation. The difference between the calculated and the measured length of one base was two-tenths of a foot. Twenty-six triangulation points were established at convenient places about the city and served as points with which to connect the main traverse lines. The triangulation cost about $200. The area to be surveyed was divided into districts of such size as could be plotted on sheets of mounted paper, 60 inches wide and 8 or 10 feet long. Streets, streams and sometimes property lines, were the assumed boundaries of the districts. For all, except the sparsely occupied districts, a scale of 40 feet to an inch was used. Each district would cover 200 to 250 acres. In surveying, the method was to first run the traverse around the district, connecting with convenient triangulation points. Galvanized iron ship spikes, 12 inches long, driven about 6 inches below the surface of the ground and covered with a flat stone, were used as traverse points where there was nothing better. Smaller wire spikes were set at points on traverse lines, near intersections of streets or at other places where it would be convenient to connect, to the main traverse, the intermediate transit lines running through the district. When it came to filling in the location of streets and property boundaries, the best way was found to be for a party of four, consisting of the man in charge, a transit man and two tape-men, to go onto the ground and locate everything they could find which marked the division of property, and to seek, from the occupants of the land, information as to the boundary lines. Buildings were not located, except in the business portions of the city. At the office, the data for a district are plotted on a sheet of best cloth mounted paper, 5 x 8 or 10 feet. It is important to take particular care to have the paper seasoned after being unrolled, as otherwise it is

likely to shrink about ¼ of an inch in 48 inches. Deeds of property are then examined, and additional measurements on the ground are made, until the size and ownership of each lot of land in the district has been satisfactorily determined. The area of each lot is figured. The sheet is then inked. It shows street lines, property division lines, streams, etc., also the dimensions, the area and the reference number of each lot. The intersections of the main survey lines used in plotting are also indicated by a red circle around the needle hole. To furnish the Assessors with plans, information was traced on the large district maps, on tracing cloth in sheets 24 x 36 inches. The sheets were bound around the edges with narrow silk ribbon by machine. Eyelets were set through the ribbon at one end of the sheet, and where these had been bound together in a folio, the work was complete. Each sheet is indexed on an index map of the city, to a scale of 800 feet to an inch. The names of the lot owners are indexed in a book, by the reference number shown in red on the plan. The book is so arranged as to allow for transfers and is kept up to date by an examination, at intervals, of the transfers at the office of registry of deeds.

The cost of this map work, covering the area of 4,600 acres, and including the time given it by the City Engineer, has been estimated at $6,400.

It is an example of the third and cheapest class of property maps. The plans meet all the needs of the Assessors, and the City Engineer's office is provided with data and with district plans which will be of great use. In this case the triangulation is made only for the purpose of checking the traverse surveys.

Besides what has been noted under maps and surveys of the first class, it occurs to the writer to mention a rather uncommon use of property maps. It is a use, however, which, provided the plans have been completed with a good degree of care, can be made of great advantage in any city.

There are some cities in this country—for instance, Philadelphia—where, if the owner of a tract of land wishes to have it subdivided, he must apply to the authorized surveyors of the city; and if he wishes to transfer a piece of land, the deed of transfer must be recorded not only by the registrar of deeds, but also on the city maps of all properties, which are an authorized record of land titles. Such a record is of great convenience to the public. Persons are thereby enabled to ascertain from an official plan what they are buying or selling.

The writer is reminded of a feature of the system of surveys of the City of Philadelphia, closely bearing on the subject of property maps. The absence of this or a similar system is a serious hindrance to the improvement of cities, for generally the City Councils have no powers

as to the location of streets, in the course of the subdivision of new tracts of land, until after the street is proposed by the land owners and the property is partially improved and occupied, a petition is presented, praying that the street be accepted, that is, after it is too late.

In the Philadelphia Bureau of Surveys, there are thirteen District Surveyors, each of whom is paid a salary of $3,000 per year. Among other duties, they are by law required to subdivide all property, proper hearings to the land owners being given. A fixed schedule of charges is made for such work, and the receipts go to the city treasury. Streets are laid out in accordance with an established system. Their acceptance is authorized by the Board of Surveyors, of which the Chief Engineer and Surveyor is chairman. This plan is said to work admirably.

Most cities have, however, virtually no control over the laying out of proposed streets through new districts. Each tract is subdivided according to the fancied private interests of the owner, and streets are apt to be located to suit that particular tract. At first thought is seems that a person owning a piece of land should be at liberty to cut it up into streets and lots as he may wish; but, in a city a person cannot construct a building as he may like, for that building is to be used by the public It is not reasonable that land owners should be allowed to lay out roads which of necessity become public streets, according to their private interests entirely and without regard to a general plan of streets designed to accommodate travel and to facilitate drainage, factors upon which the growth and improvement of any section largely depend.

Some of the large cities are now applying expensive remedies to overcome the results of such practice in regard to their street systems, as for instance, the city of Boston, in establishing its Board of Street Commissioners.

Legislation should be urged which would give the cities authority to have at least some control in locating proposed streets in the subdivision of large tracts.

The system authorized in Philadelphia seems to be a good example to follow. With modifications, it could be made to apply to smaller cities, and to combine the two principal features of official land surveys and official records of land titles.

The city engineer treads on dangerous ground when he urges such changes. Few others realize their necessity as he does. Thus the present state of things is likely to continue for some time, until, gradually, the larger cities see the folly of the practice, and the smaller ones take a lesson from them.

Mr. Albert B. Drake.—We are all familiar with the city that annually expects to cut down the appropriation for engineering, on the score of economy. We are also familiar with the engineer who annually

presents his carefully prepared statement of the necessity of increasing the efficiency of his department.

The practical solution of the question seems to be drawing near to the middle ground, to the benefit of both parties.

The engineer should make a careful study of the situation of the city, its surroundings and its possible future needs, carefully collecting and classifying all available information.

As a result of this study he will outline his general plan of future work

All surveys should be referred to some well-defined lines or monuments, as a link in the chain of improvements.

All levels should be referred to one fixed datum.

If it is impossible to do so at the time, they should be referred to fixed and permanent points which can be connected with an established base (at some future time).

At the end of the working season the compilation and classification of working material should begin. After arranging the information on hand the collecting of data for future work should be taken up.

A careful outline copy of property lines on record should be undertaken at once, especially in such territory as will call for improvements in the near future.

The deeds should be drawn out on convenient sheets for reference, and carefully indexed for future use.

Lines of levels should be carefully run in various directions through the city and references made to well known and permanent points in each section. All level work and profiles taken in the past should be reduced to the adopted datums. All surveys of street lay-outs and of improvements should be made with care and connected to well-defined points. Mo doubt should remain in the engineer's mind as to the accuracy and completeness of his work when finished.

Immediately upon approval of his work all points of reference should be permanently marked.

The notes of the surveys should be clearly and carefully made, and any uncertain or doubtful measures or lines should be distinctly marked as such.

If this system is followed the engineer will soon be able to accomplish a great amount of work with a limited force.

He will have accumulated :

1st. A record and outline of the property lines of the city.

2d. A record and outline of all streets accepted, and of the existing monuments and points of reference.

3d. A connected and thorough record of all existing improvements.

4th. A careful set of levels over the entire city.

With this information in hand, and with his knowledge of the work, all problems of improvements can be studied and projected.

The information thus obtained may now be arranged in such manner as the engineer may prefer. The information obtained from deeds is of the first importance, being the legal record with which all improvements come in contact.

With regard to map work, I have arrived at the following conclusions:

1st. All maps should be made on the best of paper.

2d. They should be made on sheets, if possible.

3d. The largest sheet should not exceed 24″ x 36″.

4th. Not more than two sizes of sheets should be used.

5th. Maps should be finished in lines without coloring.

The adoption of large and clumsy maps, when not absolutely necessary, should be avoided.

Mr. Desmond FitzGerald.—I think it should be widely known that the State of Massachusetts, through the Topographical Survey Commission, having completed a set of maps showing the topography in the State, is now engaged in surveying all the boundaries of every town and city in the State. The boundary points are all determined by triangulation and connected with the great system of primary triangulations. The latitude and longitude of each of these points are calculated. The results of the surveys are entered in separate portfolios for each municipality.

This survey is now completed for about one-third of the whole State. While the work has not yet been published, it is accessible at the office of the Topographical Survey.

THE RELATION OF THE CITY ENGINEER TO PUBLIC PARKS.

By John C. Olmsted.

In treating of this subject, I shall give first my ideas as to the City Engineer, then those as to Parks, and finally those as to the relations between the two.

Having had professional intercourse with a considerable number of city engineers, I am able to say that there is no more honest, conscientious, hardworking, and underpaid class of men than our city engineers. Still, they are not perfect, and, if they are willing to acknowledge this, as I hope they are, they will welcome a few good-natured criticisms and suggestions from a member of an allied profession.

Many city engineers are "self-made men," that is, having more than the average natural ability, they have fitted themselves for their position, in spite of having had to earn their living from too early an age. More have had as good a general and technical education as the average business man. Few have had what is called a liberal education supplemented by a thorough technical preparation for their profession before beginning work. This is much to be regretted. Every ambitious young man, intending to be a civil engineer, should secure the best possible liberal education that his circumstances permit, and his desire to get into practice should not be allowed to interfere with this.

Every man of intellect and strength of character should be liberally educated ; that is, he should have breadth as well as depth of learning. He should know "something of everything, as well as everything of something." He should have at least a smattering of all the branches of learning that distinguish a civilized community, as well as a very thorough knowledge of the principles and details of his chosen profession. Otherwise, he cannot well do his duty as one of the leaders in the intellectual life of the community. It is especially important that the city engineer should have a cultivated taste, as well as a varied fund of useful knowledge; that he should develop his creative, artistic faculties, as well as his scientific and inventive faculties, because he controls, directly or indirectly, the form taken by many of the most conspicuous and permanent constructions of a city.

The Mayor and Common Council, though they nominally have the power to direct the construction of public work, are, nevertheless, owing to the shortness of their terms of office and to their lack of technical knowledge, less able to impress their ideas upon the work, than is the city engineer, who holds his place through successive administrations. Of course, the work of the city engineer is, in one sense, well done, if it is satisfactory to the city government, but his responsibility should not end with the attainment of that standard. He knows how to build strongly and in a workmanlike manner, but he should also know how to make sure that his work shall be well proportioned and pleasing to the eye.

The style and character of the city engineer's work have a very important bearing upon the higher life of the community he serves. If, for a permanent purpose, he puts up a really permanent structure, so that little thought and trouble and expense are needed for repairs, and for maintenance, he makes life easier for future generations and sets an example of prudence, true economy, and forethought, that is unconsciously taken to heart by untold generations, and that thus, in turn, helps many another to do likewise. But, if such a permanent structure is also ill-proportioned, baldly ugly or vulgarly ostentatious, the man

who designed and executed it, will have been the means of doing greater injury to the higher sensibilities of the people, than does the author of a bad book, or the preacher of false doctrines. Therefore, let not the city engineer delude himself with the idea that art is no concern of his.

No city, without parks, can now be regarded as well equipped. In order that the city engineer may deal properly with parks, he must know what they are. Originally, a park meant a tract of land with more or less trees upon it, and reserved for deer. Pasture, trees, water and an enclosing fence were the essential elements. The English deer park, with its rolling pasture dotted with broad oaks, beeches and chestnuts, affording shade and shelter from storms, with a river, lake or pools, and stretches or patches of wood having a dense undergrowth, in which the deer and other game can hide, is still the image called to mind by the word park in the minds of those who have traveled abroad ; and the English parks are the most beautiful, simple, and romantic in the world. Latterly, in this country, our larger cities have created public parks essentially of this type, but containing, besides the necessarily extensive provisions for the convenience of the public, all sorts of more or less incongruous features.

The term park has, however, been gradually extended so that it now includes every sort of ground devoted to purposes of public recreation.

For convenience, parks may be classified somewhat as follows :—

First, the immense parks sometimes called "reservations." These are intended especially as preserves of natural scenery and should therefore be left in or restored to their primitive or a natural condition, as nearly as possible, and the constructions needed for the public convenience should be extremely simple.

Second, the large municipal parks which may be called "rural parks." These are the least understood and the most abused of any. The want of a large rural park is but little felt so long as a city is so small that it is not irksome to walk from any part of the city out into the country and back. This is suggestive as to the motives for acquiring rural parks. The city man finds it refreshing to stroll among the hills and valleys, woods and meadows ; to get free of city pavements and of city sights and sounds. The essential purpose of a rural park may, therefore, be assumed to be to afford opportunities for quiet, contemplative enjoyment of scenery. For this purpose it is necessary to have land of such shape or of such extent as to make sure of seclusion. It sometimes happens that complete seclusion can be had in a valley or on a hillside facing away from the city, even in a comparatively small area. Usually, however, an area of from 300 to 500 acres is as little as will answer the purpose. The borders of the park should be high as compared with the

interior, and should be densely planted in order to hide houses; and the vicinity of railroads and of noisy factories should be avoided. It is very desirable to include, if possible, pleasing natural scenery, and it is important to have a fertile soil. The landscape of a rural park should appear to be, in the main, natural, and yet, to fit it for use by great numbers of people, it cannot be left entirely to nature but must be kept in good order. The trees should be native to the soil or should at least closely resemble native trees. The turf should be short and thick, but not too smooth. It should be kept short by sheep or with the scythe rather than with the lawn mower. Swamps should be drained; the dead wood of trees and the litter of woods should be removed; stagnant water should be drained off or purified; excessive deposits of scattered boulders should be removed or disguised; caving banks of earth or raw gullies should be smoothed or hidden by planting. In short, the landscape should be natural and yet not be a "howling wilderness" suggestive of wolves and rattlesnakes, of decay or neglect. Roads, bridle-paths, walks, bridges, shelters, seats, and the like, are needed to render the park enjoyable by large numbers of people with comfort to themselves and without undue wear of the turf or destruction of bushes and wild flowers. The essence of a rural park being seclusion, it follows that noisy or vigorous games, horse racing, military or civic parades, public speaking or preaching, peddling, advertising and the like, should not be allowed in them. It is still more important that their secluded parts and their broad open landscapes should not be broken up or destroyed by extensive or conspicuous artificial constructions such as museums, conservatories, zoological gardens, reservoirs, standpipes, houses and barns. Even botanic gardens, ornamental flower gardens, athletic grounds and horticultural or arboricultural specimens should be relegated to the borders of a rural park, lest they spoil its chief element of value. It should always be borne in mind that any of these things can be as well or better accommodated in smaller parks, and often with greater convenience to the public.

The third class includes the great majority of parks. The parks of this class may be called "local parks" or "city parks." They vary in size from a fraction of an acre, like a small triangle at the intersection of streets, to 100 acres or more, and are distinguished from rural parks by the comparative absence of seclusion, so that one can hardly help constantly seeing the surrounding houses and hearing the noises of the city. Nearly all the means of amusement which are demanded by the public, and which should be kept out of the rural park, can be accommodated in the city parks, if the circumstances are favorable. With sufficient study, it is often possible to secure a landscape character in city parks while combining with it, more or less intimately, such attractions

as athletic grounds, open-air gymnasiums, parade grounds, flower gardens, botanical and horticultural specimens, promenades with stately rows of trees, concert groves, fountains, statues and the like. If, however, these artificial features are crowded and conspicuous, it is usually better to design such a park on architetectural principles.

To the fourth class of parks belong those public grounds in cities which are too small or too inconvenient for the uses to which the other classes of parks are put, such as steep banks of rivers, harbors or ponds; abrupt ledges or cliffs; slopes between streets at different levels; strips between railroads and adjoining streets, canals, rivers or ponds; land about reservoirs, standpipes, quarries, gravel pits, and the like. Such grounds may be made agreeable to look at and may thus become ornaments to the city. If the public is not to be allowed in them, they may sometimes be made to bear a luxuriant growth of vegetation of a much more intricate and bosky character than would be convenient in ordinary city parks. Sometimes it is best to have the more simple effect of turf and trees. Sometimes these grounds may be so situated that they can be appropriately planted with flowers in a formal, decorative manner.

Having described what a city engineer should be and what a park of each of four classes should be, I will now indicate what should be the relation of the city engineer to the parks.

The city engineer is to the city very much what the family physician is to the family. He is constantly called upon to advise and direct in all matters pertaining to his profession. He is not expected to know every branch of his profession as well as the specialist in each branch, but he does know the character, constitution, particular needs and idiosyncracies of the city, as the family physician knows the constitutions of the family. Just as the family physician calls a specialist into consultation in cases requiring expert advice which he may not feel competent to give, so the city engineer should, in all cases of sufficient importance, secure the services of the specialist in sewerage, in water supply or in park designing. He should be quick to realize that a man who has prepared himself by years of careful study and by wide experience in designing parks, is likely to secure more satisfactory results than he can who has not had such special experience. The city engineer should, therefore, be the very one to suggest and to urge the employment of experts whenever the case is of sufficient importance to justify it, and should not wait until it is urged upon him. The fact that the city engineer has designed and built city roads and walks, is supposed by many persons to fit him to design such roads and walks as may seem to be needed in the parks. The results are almost without exception distressingly bad, in the opinion of those qualified to be judges of landscape. In most cases the city engineer lays out

park roads on much the same principles that would govern him in running a railroad, the chief difference being that he smooths the side slopes and seeds them down to grass. He seems to prefer short straight stretches of road, alternating with ungraceful radial curves, with steep, abrupt side slopes and stiff rows of trees. In other words, he seems to prefer *not* to harmonize his work with the landscape, but to make it everywhere obvious and distinct. He unhesitatingly sacrifices the landscape to economy of construction, and is well content if convenience and neatness are obtained, though beauty and naturalness be absent. But the main trouble with the city engineer as a designer of work in parks is that he is often disposed to solve the problem presented by each element of a park, independently of every other. One year he will lay out a needed piece of road. Another year he will dig a pond, or build a conservatory, or lay out a zoological garden, each in the place where it is most convenient and economical, and where it will have pleasant surroundings, but rarely, if ever, with due consideration for the effect on the design of the park as a whole. If the city engineer were to build a great city hall without the aid of an architect, without any general plan, without following any recognized style; without knowing in advance what accommodations are to be provided for, and without adopting a definite scheme as to the particular materials which are to show on the outside, he would produce no more mixed and inharmonious results than he often accomplishes in public parks under the direction of the average park commission. The public has at last become sufficiently educated to know that an architect should be employed to make plans for a building before work is begun, and that radical and inharmonious changes of plan should not be allowed during construction, but it still permits much money to be spent on parks without regard to any comprehensive plan and without the guidance of a competent designer. The city engineer, at any rate, ought to know that a park should be built according to a preconceived plan, just as water-works and sewerage systems are. He should know that the parks of a city ought to be located and designed in a systematic way, one supplementing the deficiencies of another and not simply duplicating its characteristics, and also that they should be provided for in advance of the actual necessity for them. The city engineer is becoming the most important director of the material development of cities, and his office is becoming more and more a permanent one. He is thus to a certain extent responsible for holding the successive political officials to a consistent, progressive policy in all the branches of work under his charge. To him, even more than to the successive mayors, falls the duty of serving as the intelligence and brains of the municipal government in all physical matters. To no one, therefore, can an appeal for a wiser management of public parks be more fittingly addressed.

WATER WORKS—OFFICE RECORDS.

By Dexter Brackett.

In no branch of municipal engineering is it more important to keep full and careful records than in the work of the water department. A very large proportion of the plant is buried from sight, and in these times, when the demand for underground conduits for electric lighting, telephone and telegraph wires, steam heating, etc., is constantly increasing, the streets are becoming so filled with pipes that difficulty is experienced in finding space for additional lines of pipe. Under these conditions, the importance of complete and accurate records of the location of every water pipe is very manifest.

In the office of the City Engineer of Boston, the principal records kept, relating to water supply, are the following, and it appears to the writer that these should be kept in every water-department office.

(1) Records relating to water pipes, gates, and hydrants.

(2) Records relating to work done by pumping machinery.

(3) Records relating to rainfall, and the flow of streams, consumption of water, pressure in mains, etc.

(1) RECORDS RELATING TO WATER PIPES.

All water pipes and special castings should be made to conform to standard weights and dimensions; they should be carefully inspected at the foundry where made, and weekly statements of every casting inspected should be filled out, and returned to the central office. From these sheets, the numbers and weights of all castings should be checked when the castings are received from the foundry.

Monthly reports should be kept of all pipe and other material used, and of stock on hand at the beginning of each month.

The Assistant Superintendent, the Engineer, or the foreman in charge of pipe laying, should render weekly reports of the length and size of pipe laid in the different streets, the number of gates and hydrants established or abandoned, and the location of the pipe with reference to the line of the street, also the location of all branches. These reports can be filed in book form, and indexed by streets. In Boston, the engineering department checks the measurement of the pipe, and carefully locates all gates and hydrants.

The system of record plans in use in Boston is as follows: The entire system of pipe distribution is shown on a set of plans, 150 in number, on a scale of 100 feet to an inch. The different sizes of pipe are shown by different colors, and the gates and hydrants by black lines or dots. These plans are on sheets of double elephant size.

Plans of intricate and important connections are made on plans of larger scale, and copies of these are bound in pocket-book form for ready reference by the superintendents.

The general system of pipe distribution, gates, and hydrants, is shown on a large plan, to a scale of 500 feet to the inch.

This is what is termed a skeleton plan, as no street lines are shown, and all of the lines on the plan represent lines of pipe.

The different sizes are designated by figures and by lines of different thicknesses. Tracings of this plan, in small sections, are made, and blue prints from these are used for ready reference.

(2) RECORDS RELATING TO WORK DONE BY PUMPING MACHINERY.

At all of the stations connected with the Boston Water Works, very complete daily records are kept of the quantity of water pumped, the coal burned, the water evaporated in the boilers, the height to which the water is pumped, the temperature of the water and the steam, etc. These records afford the means of determining the duty performed by the engines and boilers, and show from day to day, and from month to month, the degree of efficiency which is being maintained by the engineers in charge.

(3) RECORDS RELATING TO RAINFALL, TO THE FLOW OF STREAMS, TO THE CONSUMPTION OF WATER, TO THE PRESSURES IN MAINS, ETC.

Ever since the construction of the Boston Water Works, records of the rainfall, and of the yield of the different sources of supply, have been carefully kept, and, as a result, these records have become a standard of reference in all cases regarding the probable yield of sources of water supply.

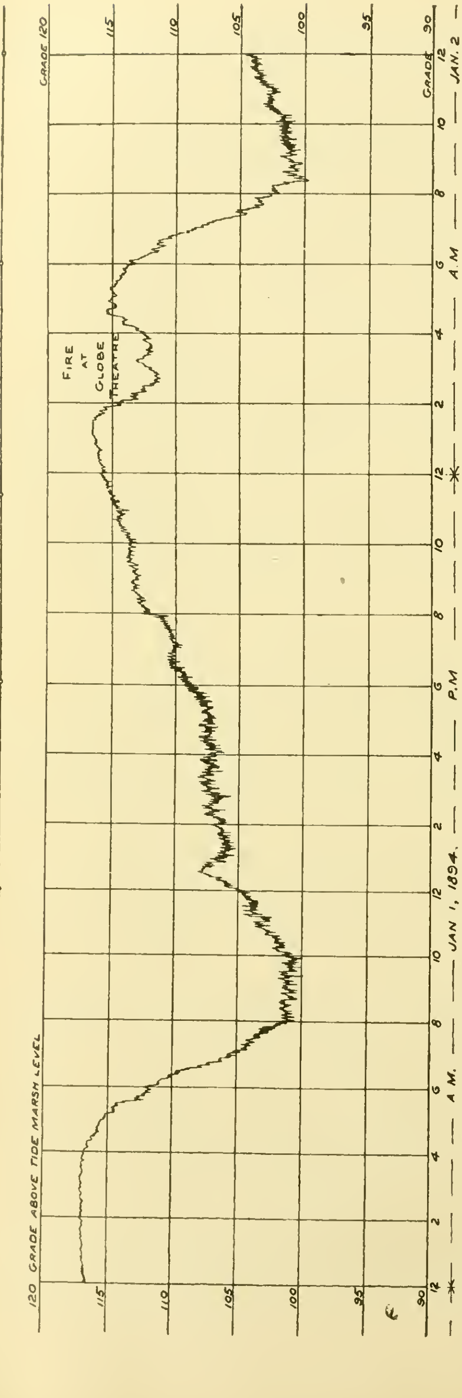
Observations of the amount of rainfall at different points, and of the elevations of the water in the reservoirs, are made daily, or oftener if necessary, and books containing records of these observations are kept by the observers.

Weekly reports are made to the City Engineer, and a duplicate copy of all the records is kept in his office. From these, the calculations of the yield of the sources of supply are made.

In order to determine the actual pressure which is available throughout the distribution system at all times of the day or night, ten recording pressure gages are located at different points about the city, affording a continuous record of the pressure in the mains.

One of these gages, located on the Common, and connected with the large supply mains, is a mercurial gage, and the record furnished by it is on a scale much larger than is often obtained by recording pressure gages.

Level of Water in Brookline Reservoir.



Sample Record from Mercurial Recording Gage, Boston Water Works. One Sixteenth of Full Size.

The diagram shown (see illustration) is but one of the many, where the actual loss of head, due to a break in a main, or to the draft caused by a large conflagration, is very graphically and accurately recorded.

The writer wishes to emphasize the fact, that records, if they are to be of value, must be carefully kept, and that, when such instruments as thermometers, pressure gages, water meters, and weighing scales, are used, care should be taken that they are kept in good order.

It is idle to install a scale for weighing the coal, and a meter for measuring the feed-water, and then to expect that, five or ten years afterward, the records furnished will be of much value, unless tests of these are made from time to time.

At the Chestnut Hill pumping station, an iron tank and weighing scale are permanently set, for the purpose of testing and rating the meters used for measuring the feed-water. Bourdon gages, when used, should be frequently tested, and for this purpose the gage tester, made by the Crosby Steam Gage Company, is a very convenient apparatus.

In the New England Water Works Association, much attention has been given to the subject of uniformity in the preparation of annual reports, and, as a result of its efforts, many cities and towns have adopted a uniform style of report. There appears to be no reason why office records should not be made, in many respects, more nearly uniform than is now the practice. For example, in the making of plans showing water-pipe systems, the adoption of standard colors to indicate the same sizes of pipe is desirable. In the preparation of annual reports, also, a greater uniformity, than at present exists, would seem to be very desirable.

Mr. A. F. Noyes.—It is probably of but little interest to most engineers to know how many dollars A, B or C received during a given year, but it is of interest to know how many dollars were spent on A's, B's or C's streets, the character and the cost of the work, and I doubt whether any State would be better able to take hold of that question than this. I hope that Mr. Brackett's suggestions will result in the appointment of a committee to report in regard to Uniformity of Municipal Reports.

Mr. Brackett.—I am sorry to say that very little system is observed in regard to record plans of the service pipes of Boston, and the only record kept has been that of the distances taken to the shut-off cock at the main, taken either from the building or from the street line, and those have been made by the Water Department. There is also a cut on the curbstone that shows the location of a pipe.

Mr. Henry Manley.—It is something like twenty-four years since the first high service was put into use in Boston. In laying pipe on Tremont Street, at the Roxbury Crossing, I found a terrible tangle of water and other pipes, and no plan of them on a large scale was in existence. I made a little plan showing the pipes and the surrounding service, and I would ask Mr. Brackett whether this was not the first plan made of the kind now in use, and whether there were any that showed the pipes more clearly.

Mr. Brackett.—There were plans showing the pipes in the city, but there were no detail plans on a large scale. There are about sixty such plans now in existence, showing the location of the gates and the lines of the pipes at all the important connections.

Mr. Manley.—I remember that we measured up all the pipes for the purpose of putting them on the plans that Mr. Brackett mentions,

and for this purpose we bought a new cloth tape, and thought it plenty good enough to measure pipes with. We used that tape industriously from morning until night, and congratulated ourselves on having got in a big day's work, but when we came to test the tape at night we found that it had stretched about a foot, and so our big day's work was lost. I have never used a cloth tape since.

Mr. E. W. Shedd.—I have been using lately a schedule which I think quite clear. In it the different sizes are indicated by different combinations of dots and dashes. It has this advantage over colored lines for showing sizes of pipes, that it can be blue-printed, photographed or lithographed, and still the sizes will be clearly shown without having to figure them in inches, or to indicate them by colors.

The system is this:

6 inch, — — — — —
8 " —·—·—·—·
10 " —··—··—··—
12 " —···—···—
16 " —·····—·····—
18 " —······—······—

The dash represents 6 inches diameter, and each dot added represents an addition of 2 inches.

This would of course become unwieldy if applied to the sizes of pipes used in large cities, but for any villages or towns it answers very well. By using two parallel lines of the same symbols the schedule can be carried up to 36 inches diameter. It is a great advantage not to have to color a blue-print after it has been printed, and the system is very convenient for printing plans in reports.

We have always made the width or weight of the line to conform to the size of pipe, making a light line or series of dashes and dots for a small pipe and increasing in width as the size of the pipe increased.

I certainly agree with the suggestion that a committee of our Society be appointed to investigate the subject of a uniform schedule, I believe that such a schedule would be of great value in many ways.

Mr. Brackett.—I think there is an advantage in using colors to indicate the pipes in office plans. It is much easier to follow the sizes and the system in color than it is even by figures or by lines of dots and dashes. Of course, however, the colors cannot be blue-printed.

The President.—There are exceptions to every good rule, and I

have found one objection to this use of color in the fact that where plans are constantly exposed to the light the colors suffer and very many of them fade seriously.

Mr. F. P. Johnson.—I have known cases where the lines representing water pipes were drawn in color and where they have become so faint that it is now almost impossible to tell the sizes of the pipes, especially since the Superintendent of Water Works is not the same person who made the plans.

We have plotted the whole city on scale of 40, and have blocked it into sections. On each of these we have shown the sewers, the waterworks etc., with the sizes of pipes by dashes of different sizes, and in addition we have used colors to indicate the sewers, water pipes, curbstones, etc., as the case may be. Our system needs no indexing, except an index sheet to be hung up in the office.

Mr. Desmond FitzGerald.—I hope that a Committee may be appointed for the purpose of considering the adoption of a uniform system.

In this connection I wish to call attention to the convenience of having all plans of as nearly uniform size as possible. In the City Engineer's office in Boston, and in the Boston Water Works, three sizes of sheets are used, viz.: Double Elephant, 25½ x 39 inches, Imperial, 20½ x 29 inches, and Half Imperial, 14 x 20½ inches. Practically about all of our work is plotted on sheets of one size, the Double Elephant, and we find it particularly useful when it comes to the filing of the plans. There is nothing more annoying in an office than to have plans on sheets of many different sizes, for such sheets are always being misplaced.

MUNICIPAL ENGINEERING IN HAVERHILL, MASS.

By J. T. Desmond.

There are many small cities in New England where public sentiment does not yet realize the losses caused to the community by the lack of system in carrying out the construction of public works and by the absence of proper records of work accomplished. Such records are especially important in the case of underground work. The expense of a special study and record of the work is considered too great, and the result is that street improvements made in one year have to be changed in the following year, and sewers without manholes are built without filing proper plans, so that in a few years the only means of getting at the facts as to location, depth, size, etc., for proposed extensions, is to

excavate the streets until the sewers are found. Many of these cities, by noting the gradual increase in the number of city engineers, are beginning to realize that this policy is a mistaken one.

In city engineering, as in all other city matters, the area, and the ratio of population to valuation, are all important factors in determining the organization of a city engineer's office and the best methods of carrying on its work.

The city of Haverhill, Mass., is large in area, but comparatively small in population and resources. The following are approximate figures: Area within the city limits, 24 square miles; population, 30,000; valuation, $20,000,000, engaged principally in the manufacture of boots and shoes; tax receipts, 1892, $360,000; expended in 1892, for streets, $80,000; for sidewalks, $12,000; for sewers, $6,000; for parks, $6,000. There are within the city limits about 110 miles of streets and ways, including 2½ miles of granite block paving and 2½ miles of Telford macadam. There are about 38 miles of brick and concrete sidewalks; 24 miles of sewers, with some old ones still undiscovered. There are also about 3 miles of double track and 12 miles of single track electric railway within the city limits.

It is evident from our large area and small income, compared with some residential cities of equal population, that all departments, including the city engineering department, must be conducted on a very modest basis in order to secure the approval of the taxpayers. Some of these consider the office unnecessary, while others are willing to admit that an engineer may occasionally be required, to drive a few stakes on public work. With them, office work is of little or no account. Still others think that the tendency of a city engineer is to magnify his own importance by advocating costly and unnecessary public improvements. I am pleased to state that our missionary work during the past seven years has converted the greater part of the unbelievers.

Still, with an annual appropriation, which, after paying the engineer's salary, leaves only about $1,000 for salaries of assistants and for expenses, the question is not "What should be done?" but "What is absolutely necessary to be done at once, and what can remain until a more favorable opportunity presents itself?" The office was established in 1887, and since 1890 the engineer has been required to devote his whole time to the city work.

ORGANIZATION OF THE OFFICE.

Two high-school graduates, with special aptitude for the work, constitute the assistants during the working season. In the winter months only one is employed. An effort is made to keep one of the assistants at work in the office most of the time, in plotting notes, drafting

finished plans, and attending to all calls for information in relation to streets and sewers. While, owing to want of time and of assistants, the results are perhaps not as precise as would be required in larger cities, they are sufficiently so for all practical purposes. In this connection it may be fair to state that our central sewerage system was established in 1877 with a very complete list of benches. Our street lines are generally well defined by stone bounds, and, with the exception of the assessors' surveys, the outdoor work is nearly all connected with construction within a central area of about five square miles. Our plan work will compare favorably in general appearance with work of the same class in other cities.

INDEXING AND ARRANGEMENT OF PLANS AND RECORDS.

Two cabinets in the office, and a portion of a large brick vault built in the basement of the City Hall, contain all the plots, mounted drawings, tracings, photographs and supplies of the office. One large drawer is labeled "New Plans." At convenient intervals the plans are taken from this drawer, numbered, indexed and transferred to other drawers containing fifty plans each. All plots are also indexed and transferred to the basement vault, so that we have all our finished plans within easy reach, and all our plots secure in case of fire. All note books are similarly indexed, but, owing to the want of a safe in the office, they are not protected from fire. The plots are numbered, and are arranged in drawers marked "Streets," "Sewers," "Public Property," "Parks," "Water," "Assessors" and "Miscellaneous" respectively. The term "Miscellaneous" includes copies of plans made by other engineers, and all plans which cannot be classed under the other headings. We have also a complete record of street locations, running back to the year 1800. All previous locations are obtained at the City Clerk's office, but they are found to be of little value. There is also a sewer note-book, copied in red and black ink and properly indexed, giving the location of every sewer and manhole, so far as known.

CITY SURVEYS AND MAPS.

At intervals, when opportunity offered, surveys for a new set of assessors' plans have been carried on, in addition to the ordinary street and sewer work during the past three years. Traverses, enclosing blocks of from 50 to 200 acres each, have been run, computed and plotted on a scale of 40 feet to the inch, for the compact part of the city, and 100 feet to an inch for outlying sections, which have been recently divided into house lots. The farming sections are on the original scale of 40 rods to an inch, and are corrected to date. The original assessors' plans were made in 1870. The finished plans are on

mounted paper, size 22 by 30 inches. A record of all transfers of real estate within the city limits is, by an arrangement with the county registry, forwarded monthly to the assessors. These abstracts state briefly the description of boundaries, the price and the kind and date of the deed, with the names of the grantor and grantee. A grantor index in the assessors' office and a grantee index in the engineer's office, showing the street where the property is located, cover the past fifteen years and save many a trip to the Salem registry, twenty-three miles away. Another index shows all the transfers on any particular street for the past fifteen years. These, together with the assessors' records, are of great assistance in getting the correct names of owners on plans for street improvements or sewer assessments. All city lots are measured, and brick buildings are located, and the plans are found to be very valuable for many other city purposes. A large wall map of the city limits, on a scale of 1,000 feet to an inch, and a city atlas, showing lots with owners' names, are found very convenient for general reference. All plans of streets for acceptance or widening are made on mounted paper on a scale of 40 feet to an inch, with a vertical scale on profile of 10 feet to an inch. They show frontages, buildings and owners, with proposed lines, bearings and distances in red. Copies of all city plans made by other engineers are kept for general reference.

HIGHWAY WORK, STREET GRADES AND INTERSECTIONS.

The annual outdoor work consists in giving lines and grades for about two miles of curbstones, surveys for the laying out or widening of one or two miles of streets, lines and grades for about one-half mile of block paving and macadam, and for one or two miles of cobblestone gutters. An effort is made to limit street grades to 15 per cent., and cross-section slopes to 4 per cent. On a side hill street, a gutter is usually made on the upper side, in order that surface water from the lots may be prevented from running across the street. The street itself generally drains into the gutter on the lower side. No special rule is followed at intersections; but it is sought to make them as nearly level and as safe as possible under the circumstances. In laying out work, curb and gutter stakes are set from 40 to 50 feet apart.

The greatest trouble we have to contend with, is the fact that property owners are permitted to open up streets in whatever manner their fancy or their greed dictates; with breakneck grades, or with no grade at all. These are soon built upon, and the city is forced to accept and improve them. About all there is left for the engineer to do is to patch up these streets and make them barely passable. Extensive changes would often result in serious damage to estates. What is needed is a legislative act, somewhat similar to the Boston Board of Survey

Act, whereby all additions to the streets of a city are required to be made on some comprehensive plan, regardless of property lines. It seems to me that this is a proper subject for a petition from this Society to the Legislature of Massachusetts.

SEWER WORK AND RECORDS.

Sewer grades are generally given by 1 x 3 inch batters placed across and over the ditch at intervals of 100 feet. These batters are at a certain elevation above the grade of the sewer, and all intermediate points are obtained by sighting a pole (generally from 10 to 15 feet long) between them, the pole resting on the forward end of the last pipe laid.

Pipe sewers are seldom laid with a grade of less than 1 per cent. Some of our large brick sewers have grades of two-tenths of one per cent. On these grades are given by marking the distances in feet, inches and fractions of an inch below the tops of the upper braces placed across the ditch, generally at intervals of about 16 feet. All inlets are located either from buildings or from manholes, and plans are made, showing owners, frontages, buildings, inlets, distances between manholes locations of manholes from street corners, etc., together with the profile on horizontal and vertical scales of 40 and 10 feet to an inch respectively, showing sizes, grades, depths below surface, etc. Owing to the necessity of economizing space in the office, the finished drawings are made on tracing cloth and bound in rolls, each roll being designated by a letter of the alphabet and properly indexed. Sewer assessment sheets are filled out on a basis of assessment of 50 cents per front foot. All sewer notes are copied in ink, and are kept up to date in a book provided for the assistant in charge of sewer maintenance under the superintendent of streets.

One of the commonest questions asked of the office by citizens is: "How deep is the sewer opposite my premises?" A large wall map of the sewers, on a scale of 400 feet to an inch, gives the location, size, material, date of construction and depth below surface at manholes. This will generally suffice to answer the question at once; otherwise reference is made to the index and to the rolls of tracings already mentioned. The annual work in this line consists in giving lines and grades for one to three miles of sewers, together with surveys, plans and profiles of the same. All streets and sewers are built by day labor, which I think will compare favorably, both in quality and cost, with contract work.

WATER WORKS.

Our city has but recently obtained control of its water works. Surveys have been made of portions of the watersheds of two lakes,

together with plans showing areas and owners. Some of this land has been taken in order to protect our supply. Surveys and plans have also been made of two other lakes, showing property lines terminating in the lakes, together with owners' names. A large wall map, on a scale of 400 feet to an inch, showing the pipe system, has been placed in the office of the water board. Our efficient superintendent of the works takes very full and complete notes of all new work and of its connections with old work. We intend to make a full set of detail plans as soon as the assessors' plans are completed.

BRIDGES.

One of the duties of the office is to make a general annual inspection of all bridges within the city limits, and to report on their condition or their need of repairs. The maintenance of bridges devolves upon the street department.

PARKS AND PUBLIC PROPERTY.

Surveys for the laying out or description of boundaries of parks are made when required by the park commissioners. Plans of nearly all school and other public lots are on file. All new public buildings are staked out, and lines and grades are given for grading the grounds.

In addition to all this, the engineer is expected to make special surveys and investigations, to make out all orders for laying out streets, to attend committee meetings and meetings of the city council, to be ready to give off-hand estimates on proposed public work, to number streets, to attend court, etc. The calls on the department are increasing, and the value of its services and records is beginning to be manifest.

THE CONTRIBUTION BOX.

Members of the associated societies, and other persons, are invited to send to the Secretary, for this department of the JOURNAL, such matters of general interest as may come to their notice.

The Relations between the Chemical Constitution and the Ultimate Strength of Steel.

In a paper read before the British Iron and Steel Institute, a paper to which Mr. P. C. Gilchrist, a member of the Council, refers as "one of the most important ever received by the Institute," Mr. William R. Webster, member of the Engineers' Club of Philadelphia, gives the very valuable results of tests upon more than one thousand plates of basic Bessemer and basic open-hearth steel manufactured by the Pottstown Iron Co. and tested upon an Olsen machine at that establishment.

The chemical determinations were made on drillings from the broken test-pieces. The investigations cover the effects of carbon, sulphur, phosphorus and manganese upon the ultimate strength of the steel. They indicate that a $\frac{3}{8}$-inch plate of pure iron without carbon, sulphur, phosphorus, manganese or silicon, would have an ultimate strength of about 34,750 pounds per square inch, and the tables give the added strengths imparted by varying proportions of the elements referred to.

Carbon is found to increase the strength about 800 pounds per square inch for each 0.01 per cent. In steels containing 0.07 to 0.08 of carbon, phosphorus also adds 800 pounds for each 0 01 per cent., but the effect of the phosphorus increases with the percentage of carbon, until, in steel with 0.15 of carbon, 0.01 of phosphorus adds 1,500 pounds per square inch. Steel with 0.15 per cent. of manganese has 3,600 pounds per square inch higher tensile strength than steel free from manganese, but the effect of equal additions of manganese decreases as its percentage increases, so that when the percentage of manganese reaches 0.50 per cent., the increase in ultimate strength for an addition of 0.15 per cent. is only 1,500 pounds per square inch.

Sulphur is credited with a constant effect of 500 pounds for each 0.01 per cent., but the effects of this element are still being carefully studied. The indications are that the ultimate strengths of plates with high carbon and high phosphorus are more affected by the finishing temperature than are those with small percentages of these elements.

The practical results of the experiments are most satisfactory. The figures obtained are in current use at the Pottstown works, and out of the last one thousand blows graded by means of them, 98 per cent. met the requirements of the orders and were accepted.

The author, who has treated of this subject in papers read before the American Institute of Mining Engineers, August, 1892, and July, 1893, refers in the highest terms to Mr. H. M. Howe's recent experiments on the heat-treatment of steel, and to the investigations of Mr. A. Lanz, of the Peine Works, upon the effect of oxygen in increasing the hardness and decreasing the ductility of steel.

The author's results are given in twenty-one tables, the preparation of which must have involved a vast amount of labor, and it seems regrettable that plottings of some of them at least have not been printed with the paper.

For convenience in applying the results obtained, three of the tables give, in pounds per square inch, in tons per square inch, and in kilograms for square millimeter, the increase of strength due to each small addition for carbon, phosphorus, manganese and sulphur.

In conjunction with Mr. Howe, Mr. Webster has prepared, by way of suggestion, the following

Lines of Investigation of the Physics of Steel.

THE PHYSICS OF STEEL.

I. Correspondence between chemical composition and fracture, micro-structure and physical properties.

II. Influence of—

<table>
<tr>
<td>(1) Casting temperature
(2) Manner and temperature of heating.
    (a) For rolling.
    (b) For annealing.
(3) Work.
(4) Finishing temperature.
(5) Rate and mode of cooling.
    (a) After forging.
    (b) For casting.</td>
<td>on</td>
<td>(a) Fracture.
(b) Micro-structure.
(c) Physical properties.
(d) Tensile properties.
(e) Residual stress.</td>
</tr>
</table>

III. Segregation as affected by—

- (1) Composition.
- (2) Casting temperature.
- (3) Rate of cooling.

IV. Blow-holes and pipes; their volume and position as affected by—

- (1) Composition.
- (2) Casting temperature.
- (3) Casting pressure.
- (4) Rate of cooling.
- (5) Special additions.
- (6) Forging.

V. Hardening; relation between tensile properties and hardness of quenched steel, and—

- (1) Quenching temperature.
- (2) Quenching medium.
- (3) Size of piece quenched.

THE LIBRARY.

It is proposed to notice briefly, in this department of the JOURNAL, such engineering publications as may find their way to our shelves.

Publishers are requested, in sending works for review, to state the prices of same.

The Elementary Principles of Mechanics. Vol. I. Kinematics. By A. Jay Du Bois, C.E., Ph.D., Professor of Civil Engineering in the Sheffield Scientific School of Yale University. First Edition. New York: John Wiley & Sons. 1894. $3.50.

Professor Du Bois is so well and so favorably known by his treatise on Graphical Statics and by his later work on The Strains (Stresses) in Framed Structures, that his treatise upon The Elementary Principles of Mechanics, of which the present volume is the first instalment, will be sure to meet with a hearty welcome from all those who are engaged in the scientific study of this subject.

The volume, owing to the absence of leads between the lines, is far more bulky than its 225 pages would at first indicate, and those who are to be frightened from such a study by a prospect of plenty of solid work had better take up some other treatise.

The present volume deals with the general principles of kinematics, the kinematics of a point and the kinematics of a rigid system, and is prefaced by an introduction defining and explaining with great care the units of measurements and the terms employed in the science.

To those who are acquainted with Professor Du Bois' previous works it is unnecessary to say that the treatment is highly scientific and is characterized by the most conscientious care.

Catalogue of the Exhibit of the Pennsylvania Railroad Company at the World's Columbian Exposition, Chicago, 1893.

This volume of 158 pages, embellished with many photographic and other representations of the exceedingly interesting objects in the Company's exhibit at Chicago, is issued in very handsome style. It is more than a catalogue and comes near being an elaborate treatise upon railroad history and practice. Not only are the means of conveyance, both ancient and modern, as exhibited in the Company's display, most satisfactorily illustrated, but great numbers of the very interesting historical documents embraced in the collection are also shown, generally upon a reduced scale. The exhibit is now installed in the Field-Columbian Museum, Chicago.

The Municipality and County. A Monthly Journal of practical information for Muncipalities and Counties and parties dealing with the same. Vol. I, No. 1. Buffalo, N. Y. $2.00 per year.

This paper, which comes to us in its first number, and which is published by the Niagara Publishing Co., Buffalo, N. Y., appears to be the outcome of the Convention of Commissioners of Public Works, suggested by Mr. M. J. Murphy, Street

Commissioner of St. Louis, and already mentioned in our Contribution Box. A large part of the present paper is devoted to an account of the proceedings of the Convention, which was held in Buffalo, September 19, 1894, and which adjourned to meet in Cincinnati a year later.

The paper comes in handsome shape, and it is evidently the intention to amuse and interest as well as to instruct the reader.

Louisville Water Company. Thirty-sixth Annual Report of the President and Stockholders for the year ending December 31, 1894. Louisville, Ky., 1894.

Mr. Hermany, chief engineer and superintendent, a gentleman of national reputation as an engineer, here presents us with a most elaborate report of the department under his charge, made up in great part of elaborate and very handsomely presented tables of pumping records, locations of pipes, valves, hydrants, etc. As an appendix is given a report by Mr. F. W. Dean, expert for the Louisville Water Company, and Mr. Dexter Brackett, expert for the I. P. Morris Company, and member of the Boston Society of Civil Engineers, in which they describe their test of pumping engine No. 3, designed by Mr. Hermany and by Mr. E. D. Leavitt, of Cambridgeport, Mass., and built by the I. P. Morris Company, of Philadelphia. They reached the conclusion that

"The duties, steam consumption, mechanical and thermodynamic efficiencies of pumping engine No. 3, as given in the preceding pages, are remarkable in establishing this as the most economical compound or double expansion steam or pumping engine that has ever been tested, so far as we are aware. It is furthermore remarkable in its mechanical efficiency, as shown by the small friction of the machinery, and this contributes considerably to the duty.

"It is with great satisfaction that we are able to make this statement without qualification, and to further state that the whole plant is a great credit to the designers and builder."

Pray's Steam Tables and Engine Constants. By Thomas Pray, Jr., C.C. and M.E. 1894. New York: D. Van Nostrand Co. London: E. & F. Spon.

We have here a series of valuable tables for steam users, embracing the ratio of expansion for different cut-offs, heat units in water at different temperatures, factors of evaporation for different temperatures and pressures, etc. The tables are preceded by 34 pages of instructions as to their use. Here the author's familiarity with the subject has unfortunately militated against the usefulness of his book, for many of the instructions are very difficult of comprehension. A little attention to the rules of rhetoric in this portion would greatly have enhanced the value of the publication.

A Text-Book on Roads and Pavements. By Fred. P. Spalding, Assistant Professor of Civil Engineering in Cornell University. 213 pages, $4\frac{1}{2} \times 7\frac{1}{2}$ inches. 12mo, cloth. $2.00. New York: John Wiley & Sons, 1894.

In the forties, the relative importance of roads and of railroads was such that Gillespie not only treated of both in a single volume of some 300 pages, but devoted to the latter subject but one of his six chapters. It is hardly necessary to say that since then these conditions have been in great measure reversed, and that the railroad has had the lion's share of the literature of land transportation.

The present little volume, devoted entirely to country roads and city pavements, indicates the extent to which the highway, as well as the canal, has of late years asserted its claims to consideration. In his preface the author refers to the present awakening of public interest in the subject and to the probable development of it as a new field of engineering activity.

The aim of this work is rather to set forth in convenient shape the principles which must underlie all proper road and pavement construction, than to treat in detail of the methods actually employed; yet these necessarily came in for more or less notice, and they are in general satisfactorily, although briefly, handled. Under city pavements the author devotes one chapter each to brick, asphalt, wood, and stone blocks.

Hydrostatics, A Treatise on ——. By Alfred George Greenhill, Professor of Mathematics in the Artillery College, Woolwich. London: Macmillan & Co., and New York, 66 Fifth Avenue, 1894. 536 pages, 4½ x 7 inches, including index. $1.90.

In this work the author aims to present, in convenient form, the principles of hydrostatics, including those of the related sciences of pneumatics and thermodynamics. A chapter is devoted to pneumatic machines, under which the author treats briefly of the balloon, the gas holder, the diving bell and diver's dress, water and air pumps. The title gives no indication of the fact that the subject of hydraulics is treated, but a short chapter is devoted to a few of the problems usually discussed under that head.

The treatment throughout is rather highly mathematical; but, while the author confesses to have made a free use of the symbols and operations of the calculus, holding that "it is easier to learn the differential calculus than to follow a demonstration which attempts to avoid its use," and although he is himself the author of a work upon that subject, his use of this particular mathematical weapon seems to be reasonably limited. After discussing the hydrostatic thrust, with special reference to its application to reservoir walls, the author devotes considerable space to the theory of earth pressure against retaining walls, etc.

The mechanical theory of heat is rather briefly handled in the last chapter of twenty-three pages.

Out of consideration for the eyes of his readers, the author has adhered to the use of a uniform size of type throughout the work, but the result is, we think, rather the reverse of that intended, for the labor of finding any particular subject by glancing at the pages is thereby considerably increased. The work is handsomely and freely illustrated with diagrams specially prepared for it.

Society Proceedings.

Association of Engineeers of Cornell University. Transactions of—— Vol. II, 1893-94. Ithaca, N. Y. June, 1894.

This number presents the constitution and by-laws of the Association, lists of officers, the President's annual address and three valuable papers. The first of these is that of Mr. Clemens Herschel on "Frontinus and his II Books on the Water Supply of the City of Rome," which we have already noticed in these pages. In the second, Mr. John F. Hayford, C. E., Assistant Astronomer, International Boundary Survey, United States and Mexico, describes certain field methods used on that survey, including determination of latitude and of azimuth, a method used

in tracing long, straight lines upon the ground, and the action of heliotropes under abnormal conditions. The third paper, entitled "Some Notes on Fire Protection Engineering," is by Mr. John R. Freeman, of Boston, member of the Boston Society of Civil Engineers and of the Board of Managers of the Association of Engineering Societies. Mr. Freeman is a recognized expert on the subject treated of, and his paper is therefore one of exceptional value. It is very freely illustrated with photographs and diagrams.

American Society of Civil Engineers. Transactions of ——. September, 1894.

This number, like its predecessors, is made up of papers read before the Niagara Convention, and of discussions upon them. The papers are those of Mr. John A. Bensel, on the "Removal of Rock Forty Feet below Water Surface in the North River, New York;" by Mr. Don J. Whittemore, on the "Form of Railway Excavations and Embankments;" and by Mr. John R. Freeman, on the "Hoisting Apparatus of the Canal Head-Gates at Sewall's Falls, New Hampshire." Prof. J. B. Johnson discusses the paper of Professors Crandall and Marston, on "Friction Rollers," and illustrates with numerous diagrams the results experimentally obtained by him in investigating the area of contact between rails and the wheels of locomotives and cars.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XIII. NOVEMBER, 1894. No. 11.

CONCRETE CONSTRUCTION ON THE ILLINOIS AND MISSISSIPPI CANAL.

BY J. W. WOERMANN, C.E., MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read June 6, 1894.*]

IN this paper I shall not discuss the merits of the different routes upon which estimates have been made for the Illinois and Mississippi Canal, better known as the Hennepin Canal, the probable saving in cost of transportation, either by actual traffic or by its effect on railroad rates, or the best dimensions for the canal prism, the lock-chamber and other works of construction. It will probably not be amiss, however, to outline in a few words the general location and the engineering features of the project as adopted.

LOCATION AND ENGINEERING FEATURES.

The canal, in connection with the upper Illinois River and the commodious channel now being constructed by the city of Chicago, will provide a short route from the upper Mississippi River to Lake Michigan. The present distance by water from Chicago to Rock Island is 607 miles. By way of the Illinois and Mississippi Canal it will be 188 miles, a saving of 419 miles to all points on the Mississippi above Rock Island. The canal will provide also a shorter route from all points below Rock Island to a point 78 miles above the mouth of the Illinois River.

By the present project the canal will extend from a point 1¾ miles

* Manuscript received Sept. 13, 1894.—*Secretary Ass'n. of Eng. Socs.*

above the town of Hennepin, at the great bend of the Illinois River, by way of Bureau Creek Valley, Penney's Slough, Rock River and a section of canal around the lower rapids of Rock River to the Mississippi at the mouth of Rock River, or the lower end of the city of Rock Island, distance of 77 miles. A navigable feeder will extend from Rock River, near Dixon, Ill., to the west end of the summit level, a distance of 35 miles.

Leaving the Illinois River, the canal reaches its summit level at the twentieth mile, after an ascent of 205 feet, through twenty-four locks, with lifts varying from 3 to 10 feet. The summit level is 5 miles in length, and is connected with the Mississippi River by a descent of 102 feet, through fourteen locks, with lifts varying from 5 to 12 feet. The feeder has a total fall of 2.5 feet in thirty-five miles, with a guard lock at the upper end. In addition to the locks already mentioned, the principal works of construction are six aqueducts, ranging in length from 150 to 420 feet; seventy-three culverts, with openings varying from 3 to 30 feet; five dams, with heights ranging from 6 to 12 feet; fifty-four highway bridges, eight railway bridges, and about 4,800 linear feet of sluices, inflows, weirs and spillways. The width of the canal at the water-line is 80 feet, and the depth of water is 7 feet. The locks are 170 feet long, between hollow quoins, and 35 feet in width. The cost of the main line is estimated at $5,068,000, and the feeder at $1,858,000, making the total for the entire canal $6,926,000. These estimates, however, were made before the passage of the eight-hour law, and, in order to make them comply with present conditions, the estimates should be increased about 20 per cent.

The only work of construction so far accomplished has been done on the section of canal around the lower rapids of Rock River, extending along that river for a distance of 4½ miles from its mouth. This construction, as well as the location, plans and estimates, submitted to Congress in 1890, were made under the direction of Captain W. L. Marshall, Corps of Engineers, U. S. A. Surveys for the final location of this section were begun in November, 1890, and actual construction in July, 1892. Both have been entirely in charge of Mr. L. L. Wheeler as resident engineer. The construction of the first, second and third miles, of locks 36 and 37, and of the bridges, has been in charge of Mr. A. O. Rowse, while that of the fourth and fifth miles, and of the guard lock, sluice-ways, dams and abutments, has been in charge of the writer.

The stone in the immediate vicinity of this section of the canal is a flinty limestone, usually without bed, or, at best, in thin, irregular strata. It is cracked in all directions, and the seams are usually filled with fire-clay, so that it is entirely unfit for use, even for good rubble

masonry. The building stone most available is the Joliet limestone, which, however, absorbs water freely, and is rapidly disintegrated by the frost, as is evidenced in the locks of the Illinois and Michigan Canal, the Moline water-power dam, and many other works. On the other hand, good sand and gravel are plentiful in the vicinity of the canal, and the rock, which it is necessary to excavate in the fourth and fifth miles, is good material for crushing. With a proper proportion of the best Portland cement, Captain Marshall believed that it would make an artificial stone which would be as hard as the native building stones, and would better resist the action of the elements, and which could be much more strongly repaired, at an expense of but ten-seventeenths of the cost of masonry of natural stone. Captain Marshall's recommendation was approved, and all of the masonry for this section will be entirely of concrete. The three locks on this section are the only locks in the United States that have been built entirely of concrete; and the only precedent abroad, so far as the writer is aware, is an important lock on the Canal St. Denis, France.

In the order of their construction, the masonry structures in this section of the canal are: The abutments for two timber dams, one submerged culvert, the piers and abutments for seven Taintor gates, one guard lock, the foundation and walls of lock No. 37 (of 12 feet lift), the foundation and walls of lock No. 36 (of 6 feet lift), the abutments for one ponton bridge, and the abutments and draw-piers for one railway bridge and one highway bridge. All these are completed, except the masonry for the two swing bridges, where preparations for construction have just been commenced.

DAM ABUTMENTS.

The site of each abutment was first enclosed with an earthen cofferdam, protected with riprap, and the earth was then excavated to solid rock. The forming of the first two abutments was erected in sections, the alternate sections being first erected and filled. When the concrete in these had set, and the forms had been removed, the planking for the front and back of the intermediate sections was braced against the concrete as firmly as possible and then filled. It was found impossible to obtain by this method a good alinement for the surface of the walls, and in the case of all the masonry built subsequently, the forming for adjoining sections has been erected at the same time. The abutment on the north shore, and the two on Carr's Island, were L-shaped, the side next to the river being 40 feet, and that extending into the earth 20 feet long. The thickness at the top is 3 feet, the front is vertical, and the back extends in steps, with a tread of from 14 to 16 inches, to the base, which is four-tenths of the height. Each of these three abutments

was built in four sections, each section containing about 30 cubic yards, and constituting one day's work. The forming consisted of 2 by 8-inch studs, spaced 2 feet between centers, 2 by 8-inch plank, and 4 by 6-inch braces. In order to secure a uniform thickness, the planks were purchased with both sides dressed.

The concrete for the north shore abutment was composed of 1 part Germania (Portland) cement, 2½ parts sand, and 4½ parts broken stone. For the other two, the proportions were 1 part Germania cement, 2 parts sand, 2 parts screened pebbles, and 3 parts stone. For a thickness of 8 inches on the face, and of 5 inches on top, the proportions were 1 part Germania cement and 2 parts sand. The gravel ran from ⅛ inch to 2 inches, and the stone had passed a 2-inch screen. The unit of measure in mixing each batch of concrete was the volume of one barrel of cement; that is, the box in which the sand was measured was filled by one barrel of cement if the latter was shoveled in, and contained about 4.5 cubic feet, although the barrels in which the cement was packed contained about 3.6 cubic feet. The stone and pebbles were wetted before being measured, and about five common buckets of water added during the mixing, or as much as the mixture would take without quaking when rammed. When the mixture quakes under ramming, it is impossible to obtain thorough compacting, and the work is injured in that case also by the water which collects on the top of each layer. The sand and cement were turned over about three times with shovels and spread in a layer; then the pebbles were added, and finally the stone was dumped on, the two latter ingredients being measured with wheelbarrows. The entire mass was then turned over at least four times by shoveling from one place to another, so as to insure that every particle was handled each time, the last turn landing it in the wheelbarrows. The tampers consisted of solid castings with handles of 1½-inch gas pipe. For tamping next to the plank, a rammer 6 inches square and weighing 30 pounds was used at first, but this was subsequently cut down to 4 by 6 inches. The other rammers were cylindrical, 6 inches in diameter, and weighed 20 pounds.

The force employed on the concrete work was usually as follows:

Handling cement and measuring sand	2	laborers
Filling barrows with pebbles and stones	3	"
Mixing ingredients with shovels	8	"
Shoveling concrete into barrows	2	"
Wheeling concrete to form	5	"
Spreading concrete in form	1	"
Tamping concrete in form	5	"
Total	26	"

The abutment on the north shore contains 89 cubic yards. The cost of the abutments on Carr's Island is given in detail in the following table. Owing to the isolated position of these abutments, to the greater cost of the stone per cubic yard, to the larger percentage of cement, and partly to the relative size of the masses of concrete, the cost per cubic yard of concrete considerably exceeds the cost per unit of the subsequent work. After setting took place, the concrete was wetted thoroughly twice a day for the first few days, and then once a day for a week longer. The forming was frequently removed on the third day after filling; but the sides, as well as the top, were protected from the sun by canvas or boards for at least a week. When the forming was removed, the slight ridges produced at the joints in the planking give the walls the appearance of cut masonry.

Cost of Two Concrete Abutments on Carr's Island.

420 barrels Germania (Portland) cement	$1,428 00
125 cubic yards crushed stone	531 00
60 cubic yards pebbles	153 00
135 cubic yards sand	62 00
Lumber and iron for forms, warehouse, kitchen and platforms (charging one-quarter of the cost of same)	140 00
Carpenter work	282 00
Mixing and placing concrete	375 00
Twenty per cent. of cost of plant	80 00
Engineering and miscellaneous items	75 00
Total cost of 254 cubic yards concrete	$3,126 00
Cost per cubic yard	$12.24
Barrels of cement per cubic yard of masonry	1.65

ABUTMENT, PIERS FOR TAINTOR GATES, AND LOW RETAINING WALLS AT GUARD LOCK.

The sites for the abutment, piers, guard lock and culvert were partly in the river bed, and were enclosed by the same coffer-dam, consisting of clay and riprap. After excavating the earth and rock to the necessary depth, the foundations were prepared by excavating all clay pockets and loose rock to a reasonable depth, and filling the same with concrete. The abutment has three walls, having lengths of 30, 43 and 50 feet respectively. The cross-sections of the walls are practically the same as those just described, and the height above the foundations is from 14 to 16 feet. The piers are 6 feet by 28 feet, and 16 feet high at the upper end. The two low retaining walls below the abutment are 18 inches wide on top, 3 feet wide on the bottom, and about 5 feet in height. They have a combined length of 420 feet, with a batter of 10 inches on the front and a step of eight inches on the back.

The forming used for the abutments previously described had yielded appreciably in several places. This, together with the fact that it had been decided to install a mixer and transport the material in cars, led to the design of a heavier system of forming, which might better resist the shock produced by a cubic yard of concrete dropping from the car. The system introduced consisted of 8 by 10-inch timbers, spaced 4 feet between centers, for uprights; 6 by 6-inch and 6 by 8-inch timbers for braces; 4 by 8-inch timber, dressed on both sides to a uniform thickness, for planking the faces, and 2 by 12-inch rough plank for the backs. The lower ends of the inclined braces were set into gains in the horizontal braces, being held by a single 8-inch lag screw. After the uprights were plumbed, a block was lag-screwed at the upper end of each brace. The horizontal braces held the feet of the uprights, and at the other end abutted against timbers bolted to the rock. As regards first cost, ease of erection, durability, strength and stiffness, the system has proved eminently satisfactory. Sufficient lumber was ordered for the erection of the entire forming for one lock wall, and by the time the bridge masonry is completed, a large part of this will have been used from eight to ten times.

The forming for the abutment was divided into sections. The concrete work in each section was continuous from bottom to top, except in the abutment and piers at the guard lock, and in the culvert. The abutment and the piers were the first pieces constructed in the season of 1893, and for several reasons it was impracticable to work more than one shift at that time. To have made the sections of such a length that they could be filled in one shift would have increased the cost of carpenter work, and would have reduced the working space in the forms to such an extent that the cost would have been very appreciably increased. The culvert was an exception to the rule, owing to the form of the cross-section, as described in a succeeding paragraph. The piers and part of the sections of the abutment were filled to a level about 6 inches below the proposed water surface, and the remainder was filled on the day following. The proportions of ingredients for the concrete were 1 part Alsen's Portland cement, 2 parts sand, 1 part pebbles and 4 parts broken stone. The thickness and composition of the facing and coping, and the method of mixing and depositing the concrete, were the same as for the abutments on Carr's Island, except that Utica (natural) cement was used in the foundations of the low retaining walls. The actual quantities of the several materials used were not determined. Data in regard to the cost will be given in connection with that for the guard lock. The amount of concrete in the abutment, including the foundation, is 343 cubic yards, and that in the piers and low walls under the Taintor gates, including the foundations, is 234 cubic yards. The

amount of masonry in the low retaining walls, including the foundations, is 267 cubic yards.

SUBMERGED CULVERT AT GUARD LOCK.

This culvert is intended to carry the discharge of a small creek, with its accompanying drift and sediment, entirely under the lock and sluice-way and into the river. This manner of disposition also prevents the water from backing over a considerable area of farm land, as it would do if it were allowed to empty into the canal. The culvert has an inside width of 10 feet, side walls 4 feet 6 inches high, height to crown of arch 6 feet 9 inches, and length of 202 feet. Owing to the shape of the cross-section, it was not feasible in this case to carry out the rule of completing one vertical section each day, and it was necessary to construct first the floor, then the side walls, and finally the arch. The floor has a thickness of 0.9 to 1.2 feet, the side walls 1 to 3 feet, and the arch 1.25 feet at the crown and 2.25 feet at the skew-back.

The vertical and horizontal timbers were 4 by 6 inch, and the plank 2 by 12 inch, rough. Although 4 feet between centers for the studs would have been close enough to support the planking for the sides, they were placed 2 feet between centers to properly support the ribs in the centers. The centers were built up of four pieces of 2 by 12-inch plank, and the lagging consisted of 2 by 4-inch lumber. No facing was used except about 3 inches next to the centers. Where the side walls exceeded 2 feet in thickness, a cheaper concrete, consisting of 1 part Utica (natural) cement, 1 part sand and 2 parts broken stone, was used next to the rock. Wherever there was a spring in the seams of the rock, a drain tile, to serve as a weep hole, was built into the concrete. The proportions of the different ingredients for the rest of the concrete, and the method of mixing and depositing, were the same as for the abutment and piers at the guard lock. The quantities and cost of the materials will be summarized in connection with the lock proper. The amount of masonry in the culvert, portals and cross-wall at end of south lock wall, was 594 cubic yards.

MASONRY FOR TAINTOR GATES AT MILL CREEK.

This consists of three piers, 6 feet wide and 30 feet long; and two abutments, 4 feet wide on top, 6 feet at the bottom, and 30 feet long, with additional wing walls, 14 feet long, running at an angle of 45°. One of the abutments is provided with two wing walls, but the other with only one. Their greatest height is 11 feet. The design of forming, proportions of ingredients, and method of handling the materials were the same as for the abutment and piers at the guard lock. The quantities of the ingredients, and their cost delivered at the gates, are shown

in the following summary. The cost of stone is low because half the cost of excavation is charged to the 4th and 5th miles.

COST OF MASONRY AT MILL CREEK TAINTOR GATES.

664 barrels Alsen's (Portland) cement	$1,992 00
253 cubic yards crushed stone	278 00
116 " " pebbles	151 00
214 " " sand	193 00
40,000 feet B. M. lumber for forming (charging one quarter of the cost of same)	160 00
Carpenter work on forms	359 00
Mixing and placing concrete	878 00
Miscellaneous bills	84 00
Twenty per cent. of cost of plant	45 00
Total cost of 460 cubic yards of concrete	$4,140 00
Cost per cubic yard	$9.00
Barrels of Portland cement per cubic yard of masonry	1.44

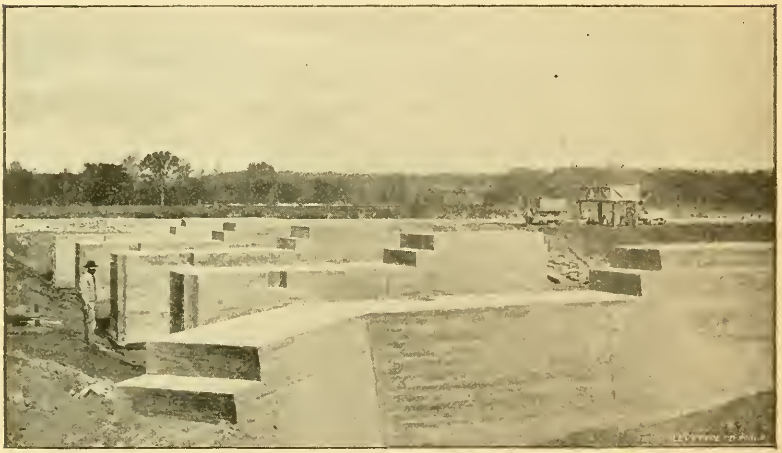
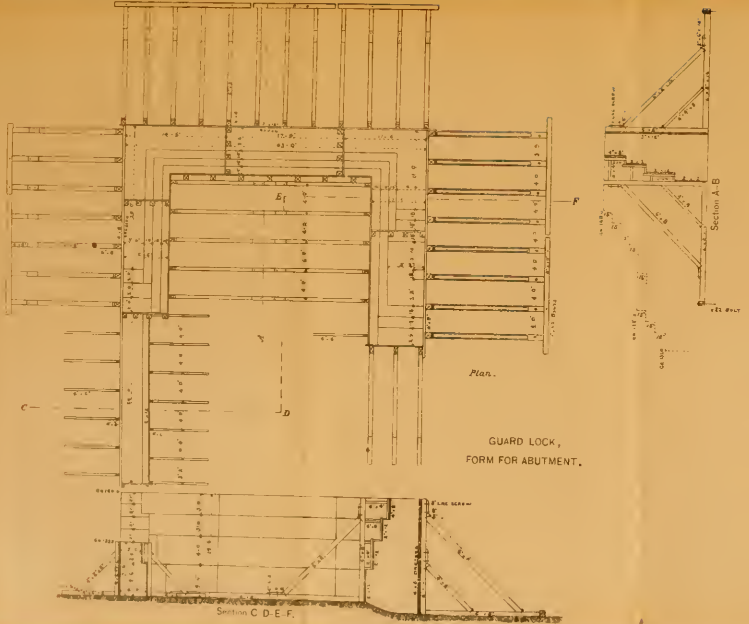


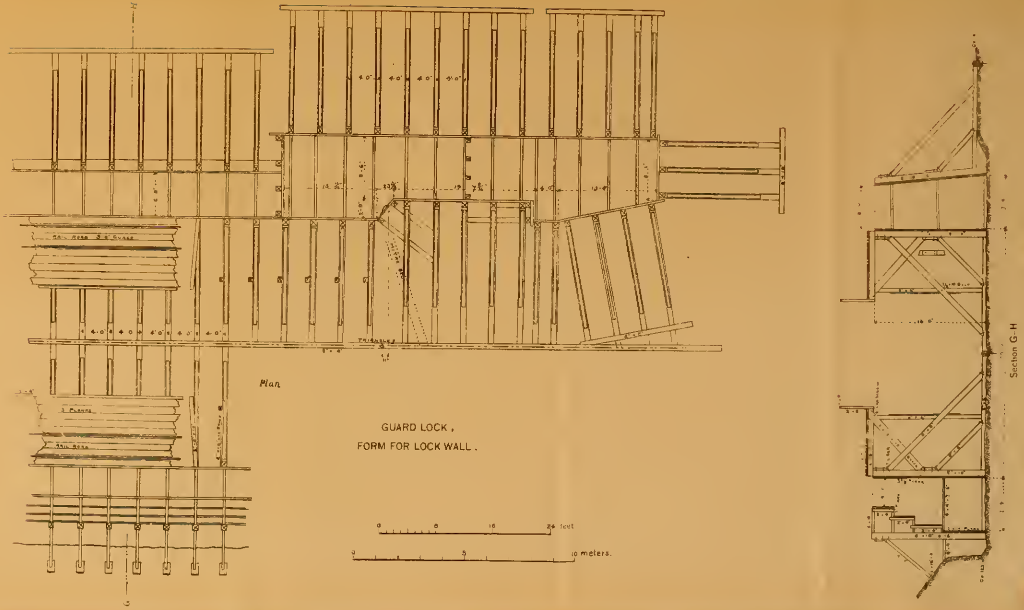
FIG. 1.—MASONRY FOR MILL CREEK TAINTOR GATES COMPLETED (OCT. 19, 1893).

CONCRETE-MIXING PLANT.

The concrete for the walls of the three locks was mixed entirely by steam, and, before referring to their construction, the mixing plant will be briefly described. It consists essentially of a truss supported by two A-frames of unequal height, the legs of which are 30 feet and 38 feet respectively. Under one end of the truss is the frame supporting a 4-foot cubical steel box, mounted on two corners diagonally opposite, and geared so as to make nine revolutions per minute. Above the mixer is a large hopper, and under the mixer is the track for the cars which transport the concrete to the lock walls. Under the other end of the truss



GUARD LOCK,
FORM FOR ABUTMENT.



GUARD LOCK,
FORM FOR LOCK WALL.

is a pit for receiving the charging box. On two sides of this pit are the tracks leading to the piles of sand, gravel, and crushed stone, while on the other two sides are the cement platform and water barrel, so that all of the ingredients may readily be dumped into the charging box. The charging box is 3 feet 8 inches square and 3 feet deep inside, holding 40 cubic feet, and is supported by a ½-inch steel cable running through a pair of double blocks. The angle of the truss is such that the cable hoists the bucket, and carries it along the truss without the use of any latching arrangements.

At the guard lock the mixer was erected as shown on the accompanying plate and it was necessary to use a canvas tube to conduct the concrete from the hopper to the mixer. When the mixer was re-erected, the hopper was lowered about 6 inches, and the spill was obviated without the use of the canvas. At the same time, the distance between the mixer and the lower platform was reduced about 9 inches, and diagonal braces were placed under the boxes supporting the axle of the mixer. At lock 36, on account of the difference in the relative elevations, the sills of the A-frames were buried about 4 feet in the ground.

A 15 horse-power portable engine drives the hoist with one pulley, and the friction clutch, which operates the mixer, with the other. The arrangement for supplying the cubical mixer with the materials was designed by Mr. Wheeler, and its operation has been thoroughly satisfactory in every respect. Nine revolutions of the box suffice to mix the ingredients perfectly. It was found, however, that the facing is not thoroughly mixed by this process, and it is, therefore, mixed with shovels. The belt hoist, trolley, charging box, and cubical mixer, with the necessary shafting, gearing, etc., cost $706, delivered at Milan, and the timber, framing and erection cost about $300 more. The framework is put together with bolts, and is readily moved from one site to another.

GUARD LOCK WALLS.

The main part of the north wall has a top width of 6 feet, and a bottom width of 7 feet 6 inches, with a batter on the back. The south wall has a top width of 4 feet, stepping down on the back to a bottom width of 7 feet 6 inches, or the same as that of the north wall. The height of the walls above the foundation is 16 feet, but for a certain distance at the upper ends, this is increased to 17 feet. The length is 238 feet. Adjoining the forming and extending the full length of each wall, was erected a trestle consisting of 6 x 6-inch posts, and 6 x 8-inch caps, connected with the forming and supporting the track for the concrete cars. Each wall was divided into sections. In order to fill a section continuously, it was found necessary to work two shifts per day on the sections of the north wall.

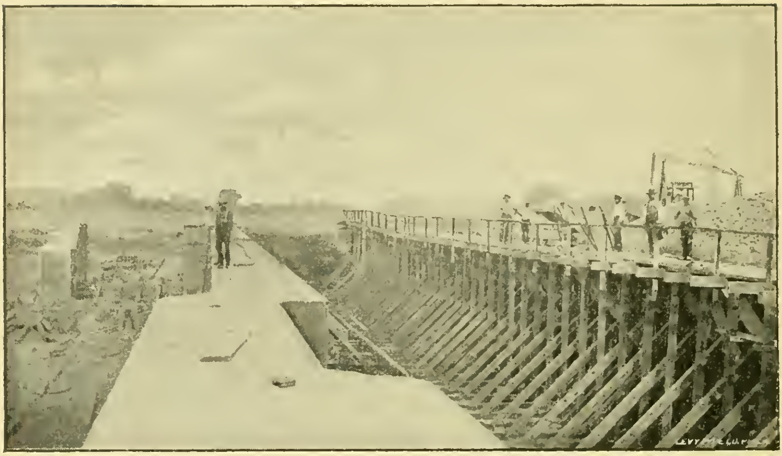


FIG. 2.—PLACING CONCRETE, SOUTH WALL OF GUARD LOCK (SEPT. 9, 1893).

Owing to the failure of two different contractors to deliver the necessary gravel on time, it was decided to build the walls without gravel, and the quantities entering each batch of concrete were: 1 barrel of Alsen's cement, 10 cubic feet of sand and 20 cubic feet of crushed stone. At each of the three locks a mixture of cement equivalent to at least five barrels was kept on hand in the cement box, so that if a barrel of poor cement got into the lot it would not be concentrated in one place in the wall. The tops of the walls were completed by heaping the forms slightly more than full, scraping off the excess with a template constructed so as to make the top of the walls slightly crowning, and then smoothing with a float, but not rubbing sufficiently to work the cement to the surface and leave a layer of sand just beneath. The layers of material were put in about six inches thick before tamping. After tamping each layer was roughened sufficiently to form a good bond with the next one.

At the guard lock, as well as at the other two locks, 12 by 12 inch holes about 15 feet apart were left near the center lines of the walls, extending down into the walls within 4 to 6 feet of the bottom. Beginning on the day after a section was completed, the holes were filled with water several times a day for at least a week, besides keeping the tops and sides of the walls wetted during the same period. At the guard lock the water disappeared from the holes much more rapidly than at the two lower locks where gravel was used. Owing to percolation through the concrete intervening between the holes and the surface, part of the water reappeared on the sides of the walls. This is regarded as indicating that these walls were not as compact as those in which gravel was used, although the ramming was equally thorough.

An average run for a day of eight hours at the guard lock was about 40 batches of facing, and 60 batches of concrete proper, representing 100 barrels of cement. The statement that the 8 inches of facing required about two-thirds as much cement as all the rest of the wall, may seem paradoxical, but is nevertheless true. The average force employed was as follows:

Handling cement	3	laborers.
Filling and pushing sand car	5	"
" " " stone car	9	"
Measuring water	1	"
Dumping bucket on top platform	3	"
Opening and closing door of mixer	1	"
Operating friction clutch	1	"
Attending concrete cars under mixer	1	"
Mixing material for facing	6	"
Dumping cars at form	2	"
Spreading concrete in form	3	"
Tamping " "	10	"
Finishing top of wall	2	"
Total	47	"
Hauling concrete cars with single horse	1	teamster.
Operating hoist	1	engine driver.
Running engine	1	" "
In charge of form	1	sub-overseer.
In general charge	1	overseer.
Total force	52	men.

The total quantities of material, and their cost delivered at the lock, for all the structures at the guard lock, including the abutment, piers, culvert, lock walls, and low walls below the abutment, are given below. The price for crushed stone is low, because it was excavated in the canal trunk, and only half the cost of excavation is charged to the lock. The quantities of masonry in the north and south walls, including foundations, are 1,181 cubic yards and 1,032 cubic yards respectively, and that under the mitre sills is 111 cubic yards.

COST OF MASONRY STRUCTURES AT GUARD LOCK.

5,246 barrels Alsen's (Portland) cement delivered at lock	$15,604 00
152 " Utica (natural) " " "	84 00
2,901 cubic yards crushed stone	2,901 00
126 " " pebbles	113 00
1,970 " " sand	1,398 00
145,000 feet B. M. lumber for forming trestles (charging one quarter of the cost of same)	659 00
Iron for forming, trestles, etc.	90 00
Coal, oils and miscellaneous bills	327 00

Carpenter work on forms and trestles	$2,726 00
Mixing and placing concrete	6,693 00
Pumping, engineering and miscellaneous labor	742 00
Twenty per cent. of cost of plant	550 00
Total cost of 3,762 cubic yards of concrete	$31,887 00
Cost per cubic yard	$8.48
Barrels of Portland cement per cubic yard of masonry . .	1.40

FOUNDATIONS FOR LOCKS 36 AND 37.

The foundation of lock 36 was the only piece of concrete work done by contract. It consisted of 564 piles capped by 10 by 10 inch longitudinal pine timbers, with concrete rammed between them to the level of the top of the longitudinals. Cross timbers of 6 by 10 inch and 10 by 10 inch pine were placed on the longitudinals, the spaces between them were rammed with concrete, and the spaces between the walls were covered with 2-inch pine blank. The concrete, except under the lower gates, consisted of one part Utica (natural) cement, one part sand, and three parts screened pebbles, while that under the lower gates consisted of one part Germania (Portland) cement, two parts sand, and four and one-half parts screened pebbles. The cement was furnished by the United States Government, and cost, delivered at Milan, $0.55 per barrel for Utica, and $3.10 for Germania. The total quantity of concrete in the foundation was 855 cubic yards, and the contract price was $5.00 per cubic yard, the contractor furnishing all material except the cement.

On account of the failure of the contractor, the foundation of lock No. 37 was constructed by hired labor. Before depositing any concrete, the soft places were covered with broken stone, and the water from a number of large springs was carried beyond the limits of the foundation by several lines of tiling. The proportions of ingredients for the main part of the foundation were 1 part of Utica cement, and 3 of gravel. A space 25 feet in width, extending entirely across the foundation under the lower gates, was excavated to a depth of 28 inches below the tops of the piles and filled with concrete, consisting of 1 part of Utica cement and 2½ of gravel. An area under each hollow quoin, however, was filled with Portland cement concrete. The arrangement of piles and timbers was practically the same as that at lock 36. At both locks the materials were hauled upon the foundation in wagons, and the ingredients were mixed by hand upon a movable platform, and shoveled directly into place without the use of wheelbarrows. The total amount in the foundation of lock 37 is 1,074 cubic yards. The mixing, depositing, and ramming cost approximately $1 per cubic yard.

MASONRY AT LOCK 37.

The main part of both lock walls has a top width of 4 feet, and a bottom width of 11 feet, with a batter on the back. The height of the walls above the foundation is from 24 to 26 feet. The lift being 12 feet, the mitre and breast walls are each 12 feet high. The thickness of the mitre wall is 8 feet throughout its height, and that of the breast wall is 4 feet on top and 8 feet at the bottom. A filling culvert, 3 feet wide

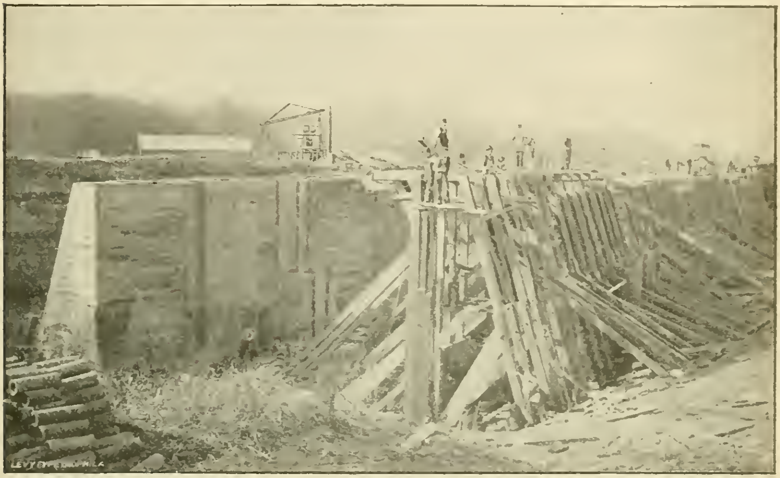


FIG. 3.—CONSTRUCTING NORTH WALL OF LOCK 37 (NOV. 10, 1893).

and 6 feet high, is constructed in each wall around the upper gate, and each wall is divided into nine sections, the largest section containing 250 cubic yards. The other dimensions of the lock are the same as those of the guard lock. Uprights, 8 x 10 inches and of the full height of the lock walls, could not readily be obtained, so that shorter lengths were bolted together to answer the purpose. It was also necessary to add a row of longer braces on each side. Two 4 x 10-inch timbers, 14 feet long, were bolted to each pair of uprights, and stiffened by a 2 x 12-inch brace, to furnish a support to the track. In other respects the forming is similar to that at the guard lock. At the guard lock, on account of the uneven rock bottom, it was necessary to raise each upright separately, but here on the grillage foundation it was much more convenient to raise them in bents. Here, and at lock 36, the timbers for holding the feet of the braces were drift-bolted directly to the grillage foundation.

In order to comply with Captain Marshall's directions to use 1 part of cement to 8 of other ingredients, the quantities entering each batch of concrete were 4½ cubic feet of cement, 15 cubic feet of a

mixture of pebbles and sand, and 20 cubic feet of crushed stone. The original plan was to use only screened pebbles in place of the natural gravel, but, on account of the failure of two contractors to deliver the requisite amount, it was decided to haul the natural mixture by hired labor. The total quantity used of each is given in the next table. The screened pebbles were used partly with sand only, and partly with the natural gravel. Ten measures of the natural gravel consisted of 4.9 measures of sand (passed through a No. 12 sieve) and 6.6 measures of pebbles ranging in size from $\frac{1}{12}$ of an inch to 1 inch.

The cross-sections of the walls being so much greater than at the guard lock, it was decided to put on three shifts, and to run continuously during the construction of each wall. It was found that, by using

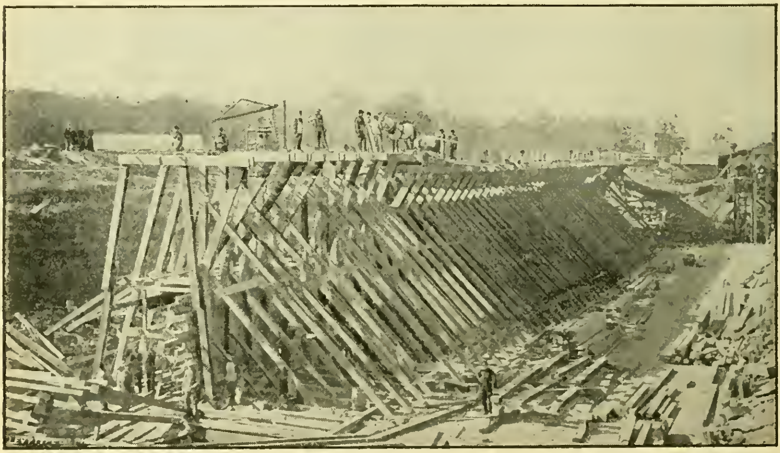


FIG. 4.—CONSTRUCTING SOUTH WALL OF LOCK 37 (OCT. 25, 1893).

six Wells lights, the concrete could be laid at night about as well and as economically as during the day. The two main walls were erected in 21 shifts and 20 shifts, respectively, or one shift less than two weeks for both walls, making an average of 86.2 cubic yards of concrete per day of eight hours. The average output per shift was 65 batches of coarse material, and 31 batches of fine material. The arrangement of the force was the same as at the guard lock, except that one or two men were added in several places, making the total force on each shift 58 men. The two main walls contain 3,536 cubic yards of masonry, the breast wall 95 cubic yards, and the mitre wall 136 cubic yards, making the total for the lock walls 3,767 cubic yards. The total quantities of material and their cost are as follows:

Cost of Masonry at Lock 37.

4,564 barrels Portland cement delivered at lock . . .	$14,181 00
2,460 cubic yards crushed stone " "	4,521 00
250 " " pebbles " " . . .	325 00
1,750 " " gravel	2,335 00
450 " " sand	450 00
180,000 feet B. M. lumber for forming and warehouses (charging one-fourth the cost of same)	990 00
Fuel, lights, repairs, etc.	1,171 00
Carpenter work on forms, trestles and warehouses	2,526 00
Pumping	270 00
Mixing and placing concrete	6,170 00
Twenty per cent. of cost of plant	730 00
Total cost of 3,767 cubic yards concrete	$33,669 00
Cost per cubic yard	$8.93
Barrels of Portland cement per cubic yard of masonry . .	1.21

Fig. 5.—Masonry at Lock 37 Completed—from North (Nov. 27, 1893).

MASONRY AT LOCK 36.

This lock has a lift of 6 feet, the height of the main walls is from 15 to 16 feet, and the other dimensions of the walls conform with these proportions. The design for the forming is similar to that used for the north wall of the guard lock. In the walls previously built, the joints between the different sections of the masonry were about $\frac{1}{32}$ of an inch wide during the coldest weather. In order to make this still less, the sections were reduced in length to about 22 feet at lock 36, so that there were eleven sections in each wall. Although the ends of the sections had been previously left rough, so as to form a bond between them,

Captain Marshall decided to improve the bond by setting up two 4 x 8 inch planks at each end of every alternate section during construction, so as to let the ends project into the adjoining sections.

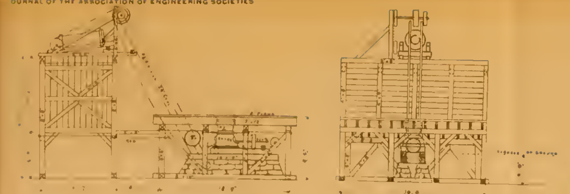
The quantities of ingredients entering each batch of concrete were $5\frac{1}{7}$ cubic feet of Alsen's cement, 16 cubic feet of a mixture of sand and pebbles, and 20 cubic feet of crushed stone, in accordance with Captain Marshall's directions to use a 1 to 7 mixture. The remarks in regard to screened pebbles and natural gravel in lock 37 apply also to lock 36. This batch made exactly 1 cubic yard when measured in place in the wall. Working continuously with three shifts was so satisfactory at lock 37 that it was resumed at lock 36. The speed of construction had been regulated at the other locks by the rate at which the tampers could do their work thoroughly. In order to increase the output, Mr. Wheeler decided to carry on two sections at once, commencing one when the other was about half completed. Two gangs of spreaders and tampers were put on, but the balance of the force remained practically the same, the total force on each shift being 65 men. The average output was thereby increased to 76 batches of coarse and 35 of fine material, the maximum being 96 of coarse and 22 of fine. The time occupied in building the south wall, containing 973 cubic yards, was 10 shifts, or 97.3 cubic yards per day of eight hours. The two main walls contain 1,819 cubic yards, the breast wall 41 cubic yards, the mitre wall 53 cubic yards, and the return walls at the east end of lock, 76 cubic yards, making a total for the lock walls of 1,989 cubic yards.

About 60 feet east of the lock are the two abutments for a ponton bridge. Each abutment has a special form to allow for swinging and protecting the bridge. The main walls, as well as the wing walls, have a top width of 2 feet, bottom width of 4 feet and a height of 10 feet. They rest on a grillage foundation, 20 inches thick, and together contain 152 cubic yards, including the foundation.

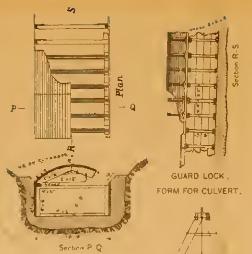
The quantities and cost of materials for all the walls at lock 36 are as follows. The increased cost per cubic yard over that at lock 37 is due to the greater quantity of cement per cubic yard of masonry, and to the greater percentage of facing per total volume of masonry :

Cost of Masonry at Lock 37.

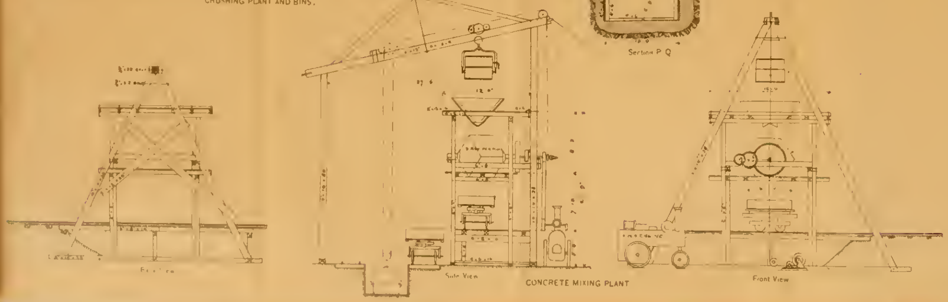
3,010 barrels Alsen's cement	$9,057 00
1,377 cubic yards crushed stone	1,922 00
393 " " screened pebbles	354 00
459 " " gravel	310 00
500 " " sand	889 00
150,000 feet B. M. lumber for forms and warehouses (charging one-fourth the cost of same)	600 00
Fuel, lights, repairs, etc.	253 00



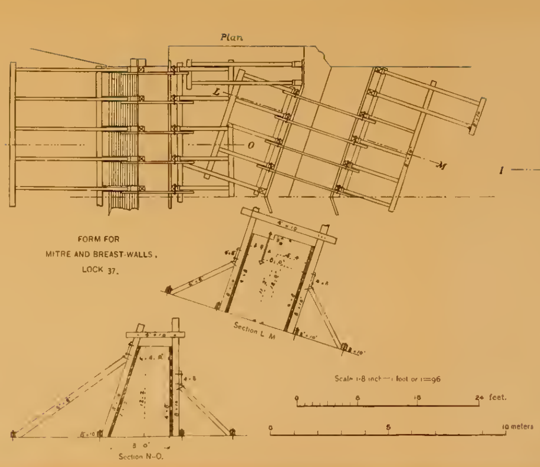
CRUSHING PLANT AND BINS.



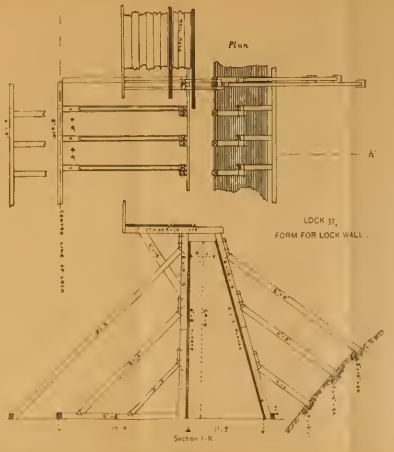
GUARD LOCK, FORM FOR CULVERT.



CONCRETE MIXING PLANT



FORM FOR MITRE AND BREAST-WALLS, LOCK 37.



LOCK 37, FORM FOR LOCK WALL.

Carpenter work on forms, trestles, warehouses, etc. . . .	1,472 00
Mixing and placing concrete, etc.	3,897 00
Twenty per cent. of cost of plant	650 00
Total cost of 2,141 cubic yards of concrete	$19,404 00
Cost per cubic yard	$9.06
Barrels of Portland cement per cubic yard of masonry . .	1.41

SUMMARY OF THE TOTAL QUANTITIES OF INGREDIENTS, WITH THE PERCENTAGE AND COST OF EACH AT FIVE DIFFERENT SITES.

Assuming that 10 measures of the natural gravel used at locks 36 and 37 represent 5 and 6.5 measures respectively, of sand and of gravel, and that 6 barrels of cement constitute a cubic yard as measured loose in the box, we obtain the following summary of quantities at the several sites.

	Two Abts. on Carr's Island.	Structures at Guard Lock.	Mill Creek Sluice Gates.	Walls of Lock 37.	Superstructures at Lock 36.
Cubic yards of Alsen's cement	70	874	111	761	501
Cubic yards of crushed stone	125	2,901	253	2,460	1,377
Cubic yards of screened pebbles	60	128	116	1,388	691
Cubic yards of sand	135	1,970	214	1,325	730
Cubic yards of masonry	254	3,762	460	3,767	2,141
Total cost of masonry	$3,126	$31,887	$4,140	$33,669	$19,404

From this we obtain the following table, showing the percentages of the dieffrent ingredients, based on the volume of the masonry:

	Two Abuts. on Carr's Island.	Structures on Guard Lock.	Mill Creek Sluice Gates.	Walls of Lock 37.	Superstructures at Lock 36.
Percentage of cement	28	23	24	20	24
" " stone	49	77	55	65	64
" " pebbles	24	03	25	37	32
" " sand	53	52	47	35	34
Total percentage	154	155	151	157	154
Barrels of cement per cubic yard	1.65	1.40	1.44	1.21	1.41
Cost of masonry per cubic yard	$12.24	$8.48	$9.00	$8.93	$9.06

For structures, where the proportions of ingredients and the proportion of facing to the total thickness of the wall are the same as here, we may, from an inspection of the preceding table, state the following approximate rules for storing the different ingredients:

(a) If the masonry is to be built without pebbles, the cement will constitute one-fourth, the stone three-fourths, and the sand one-half of the volume of the masonry to be constructed.

(b) If the masonry is to be built with pebbles, the cement will constitute one-fourth, the stone two-thirds, the pebbles one-third, and the sand one-third of the volume of the masonry to be constructed.

In either case, the volume of the masonry will be about two-thirds of the volume of all the ingredients. In the preceding rules, the cement is considered loose, and measured in cubic yards, so that a more convenient rule for the cement would be 1.4 barrels per cubic yard of masonry.

RULES FOR CONCRETE WORK.

BY CAPT. W. L. MARSHALL.

(a) All massive concrete work should be divided into sections by vertical planes, at right angles to the longest dimensions, or on approximately radial lines if curved, to determine in advance the planes of weakness, along which cracks due to contraction in setting, or to changes in temperature, shall take place.

(b) These sections must be built in successive horizontal layers, as thin as practicable, each layer being well rammed in place before the previously deposited layer shall have had time to partially set. This rule calls for continuous work, from base to coping, day and night, if necessary, and the work must be rubbed smooth on the top surface and completed without cessation of operations.

(c) There must be no definite plane or surface of demarkation between the facing and the concrete backing, but the facing and the backing must be deposited in the same horizontal layers and rammed in place at the same time. As far as practicable, the matrix or mortar of the concrete should be homogeneous from face to back of wall. It is permissible to increase somewhat the proportion of cement in the mortar near the face, in order to give greater strength, but the cement must be the same as in the concrete mass. No mixture of cement and lime, or of cements of different qualities, should be made. Diverse cement concretes should be connected by dovetails.

(d) No plastering or finishing of surfaces, other than sifting sand and cement on the surfaces, if too wet, and rubbing hard with a float, is allowable, or any practice that developes planes or surfaces of weakness other than the vertical planes already noted.

(e) The concrete and mortar shall be mixed with no more water than they will carry without quaking in ramming; they shall be deposited immediately after mixing; and shall be kept well shaded from the sun and supplied with water, at least at the surface, until well set.

TESTS.

Tensile tests of the Alsen's cement used, were made under the direction of Capt. Marshall at Chicago. The average strength of 42 briquettes of the medium setting cement (yellow label) at the end of 7 days, was 441 pounds per square inch. The average strength of 44 briquettes of the same grade at the age of 28 days, was 511 pounds per square inch. The mean strength of 58 briquettes of the slow setting cement (white label) was 501 pounds, and of 54 briquettes of the latter grade at the age of 28 days, 580 pounds. The above briquettes were of neat cement only. The mean strengths of briquettes consisting of 1 part of cement and 3 of standard quarts sand, were 122 pounds and 184 pounds respectively for the medium setting cement, and 142 pounds and 207 pounds respectively for the slow setting. The minimum and maximum strength of the medium setting were 280 pounds and 610 pounds respectively, and those of the slow setting were 437 pounds and 660 pounds respectively.

"The briquettes of neat cement were either rammed into moulds uniformly, or pressed in with a force of about 220 pounds per square inch, the variations in the two methods being small." With briquettes containing sand, however, only results from ramming with an iron bolt were used in the above averages, the strength of pressed sand briquettes being only about one-half as great. The weight of the bolt was ½ pound, the fall 2 inches and the end area 0.31 square inch. The briquettes of neat cement, before being placed in water, were either allowed to stand in air for twenty-four hours, or were left under a damp cloth for twenty-four hours, the latter method giving strengths nearly 50 per cent. greater, and indicating the advisability of shading concrete work, and of supplying it with water for at least one week after placing it in forms. The quartz sand all passed a No. 20 sieve, and caught on a No. 50 sieve.

Tests made by Captain Marshall also confirmed those made by Mr. Alfred Noble at the Cairo Bridge, and by Mr. E. S. Wheeler at Sault Ste. Marie, namely, that briquettes containing limestone screenings are stronger than those prepared with only sand. Impure limestone screenings, containing clay, as taken from the crusher, gave even greater tensile strengths than marble dust, or pure screenings. This is a paradox which the writer cannot explain, but it would seem to indicate some chemical action between the limestone and the clay, similar to that which takes place in the setting of ordinary cement.

The tests for time of setting indicated that the average time which elapsed after moulding and before the briquettes of neat cement of the medium setting samples would support a $\frac{1}{12}$ inch needle under a ¼ pound weight, was 24 minutes; and the time required for the briquettes to set hard enough to support a $\frac{1}{24}$ inch needle under a 1-pound weight, as

determined from the 42 briquettes previously mentioned, was 2 hours 5 minutes. The lengths of time for the slow-setting samples, as determined from the 58 briquettes mentioned under tensile tests, were 2 hours 21 minutes and 4 hours 22 minutes respectively. The tests for fineness of both grades of neat cement indicated that 99 per cent. passed a 2,500 mesh sieve, and 87 per cent. passed a 10,000 mesh sieve. The weight per cubic foot of the concrete, as determined from 6-inch cubes made from regular mixings at lock 36, was 148 pounds for the concrete proper, and 133.5 pounds for the facing. The percentage of water absorbed during four days immersion, as determined from the same 6-inch cubes, the cubes having been first thoroughly dried, was 2.1 per cent. for the concrete proper, and 3.4 per cent. for the facing. The tests for crushing strength have not yet been made, but they will no doubt sustain the high standard indicated by the tensile tests. The dry cement was of the ordinary gray or slate color, and the finished masonry was of about the same shade, although this depended considerably on the color of the sand. The crushed stone used passed a 2-inch ring, pieces larger than this being again passed through the crusher. The product therefore was a mixture of all sizes under 2 inch. The sand was the ordinary gray river sand, not sharp, but possessing a considerable range in size of grains.

MISCELLANEOUS ITEMS.

The weight of a barrel of Alsen's Portland cement, containing 3.6 cubic feet as packed in the barrel, or 4.5 cubic feet when shoveled into the measuring boxes, was about 395 pounds gross, or 370 pounds net. The hardness of the concrete, and its ability to resist abrasion, are roughly indicated by the fact that in setting the snubbing posts at the guard lock, a holder and a striker drilled about 10 feet of 1½-inch hole per day of eight hours, while in ordinary limestone the same men would probably have drilled 15 feet. When the ice went out of Rock River, in the spring following the construction of the first three abutments, there was an exceedingly heavy run of solid ice 12 to 18 inches thick, and the abutments withstood this with no apparent abrasion whatever.

The corners of the coping next to the faces of the concrete masonry have all been dressed to a quadrant having a 3-inch radius; this gives a very good finish. The number of linear feet which the same experienced stone-cutter dressed per day, on masonry of different ages, gives a practical idea of the hardening of the facing with age. At lock 36, when the masonry was one month old, the cutter dressed about 30 feet per day; at the guard lock, when the masonry was three months old, about 24 feet per day; and at the dam abutments, when twenty-two months old, about 18 feet per day.

The average cost per cubic yard of the facing in place was about $16.00, as compared with $8.25 for the concrete proper. In making

the estimates of cost of concrete per cubic yard, throughout this paper, the salary of the engineer in the field has been included, but nothing has been added to allow for a proportion of the expenses of the offices in Milan and in Chicago. It is impossible to state just what allowance should be made for this, but $0.15 per cubic yard would probably cover it.

At the north shore abutment large stones were deposited in the body of the wall, care being taken to tamp the concrete as thoroughly as possible around each stone, but this practice was found to interfere to such an extent with the regular program of mixing and depositing the concrete proper, that it was not resumed on any of the subsequent work. The writer believes that it is apt to result in irregular cracks on account of the imperfect homogeneity of the masonry.

PERCENTAGES OF TOTAL COST OF DIFFERENT ELEMENTS OF CONCRETE CONSTRUCTION AT FIVE DIFFERENT SITES.

	Two Abuts. on Carr's Island.	Structures at Guard Lock.	Mill Creek Sluice Gates.	Walls of Lock 37.	Superstructures at Lock 36.
Cement	46	49	48	42	47
Stone	17	10	07	14	10
Pebbles	05	00	03	05	03
Sand	02	04	05	04	05
Lumber and iron	04	02	04	03	03
Carpenter work	09	09	09	08	08
Mixing and placing concrete	12	21	21	18	20
Plant	03	02	01	02	03
Miscellaneous items	02	03	02	04	01
Total	100	100	100	100	100

In general, therefore, we may state that for this class of concrete work performed under similar conditions, the total cost will be distributed approximately as follows: Cement, 45 per cent.; the other ingredients of the concrete, 20 per cent.; lumber and iron, 3 per cent.; carpenter work, 9 per cent.; mixing and depositing concrete, 18 per cent.; plant and miscellaneous items, 5 per cent.

The total amount of concrete deposited on this section of canal up to July 1, 1894, is as follows:

Three dam abutments	343 cubic yards.
Structures of guard lock	3,762 " "
At Mill Creek sluice gates	460 " "
Foundations of lock No. 36	855 " "
Superstructures at lock No. 36	2,141 " "
Foundation of lock No. 37	1,074 " "
Walls of lock No. 37	3,767 " "
	12,402

My thanks are due to Capt. W. L. Marshall, Mr. L. L. Wheeler, and Mr. A. O. Rowse for their assistance in the preparation of this paper.

NOTES ON THE BROOKLYN ELEVATED RAILWAY OF BROOKLYN, N. Y.

By A. A. Stuart, Member of the Engineers' Club of St. Louis.

[Read June 6, 1894.*]

It is my purpose to relate in this paper some of the salient facts of the construction of the Brooklyn Elevated Railway, collected by the writer during his official connection with the Company. The topics involved will not be treated in detail, but it is hoped that some of the matter presented may, nevertheless, be of interest and value to members of this Club.

Fig. 1 shows the Company's lines and their connections, in the outlying districts, with the surface roads reaching pleasure resorts on the Long Island seashore.

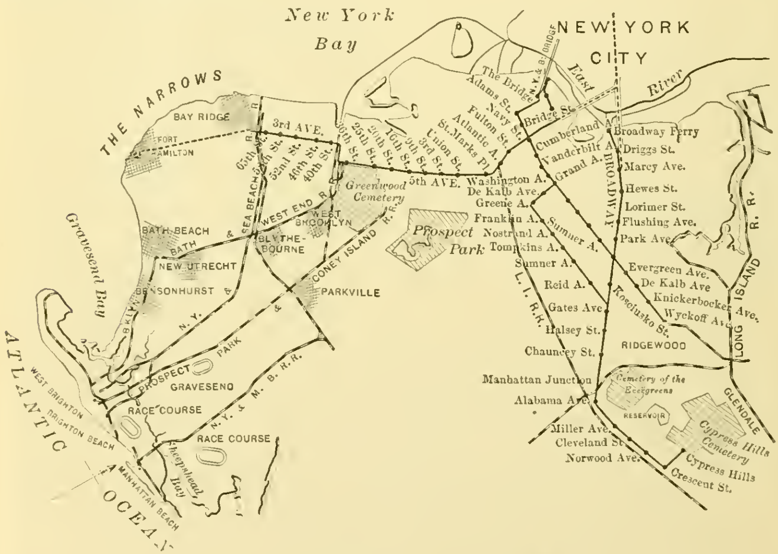


Fig. 1.—Lines and Connections.

Schemes for rapid transit in the city of Brooklyn were conceived as long ago as 1874, shortly after the completion of the first elevated railway in New York City, but it was not until 1884, or after the New York lines had become a pronounced financial success, that any material financial support was secured for this, which is one of a number of

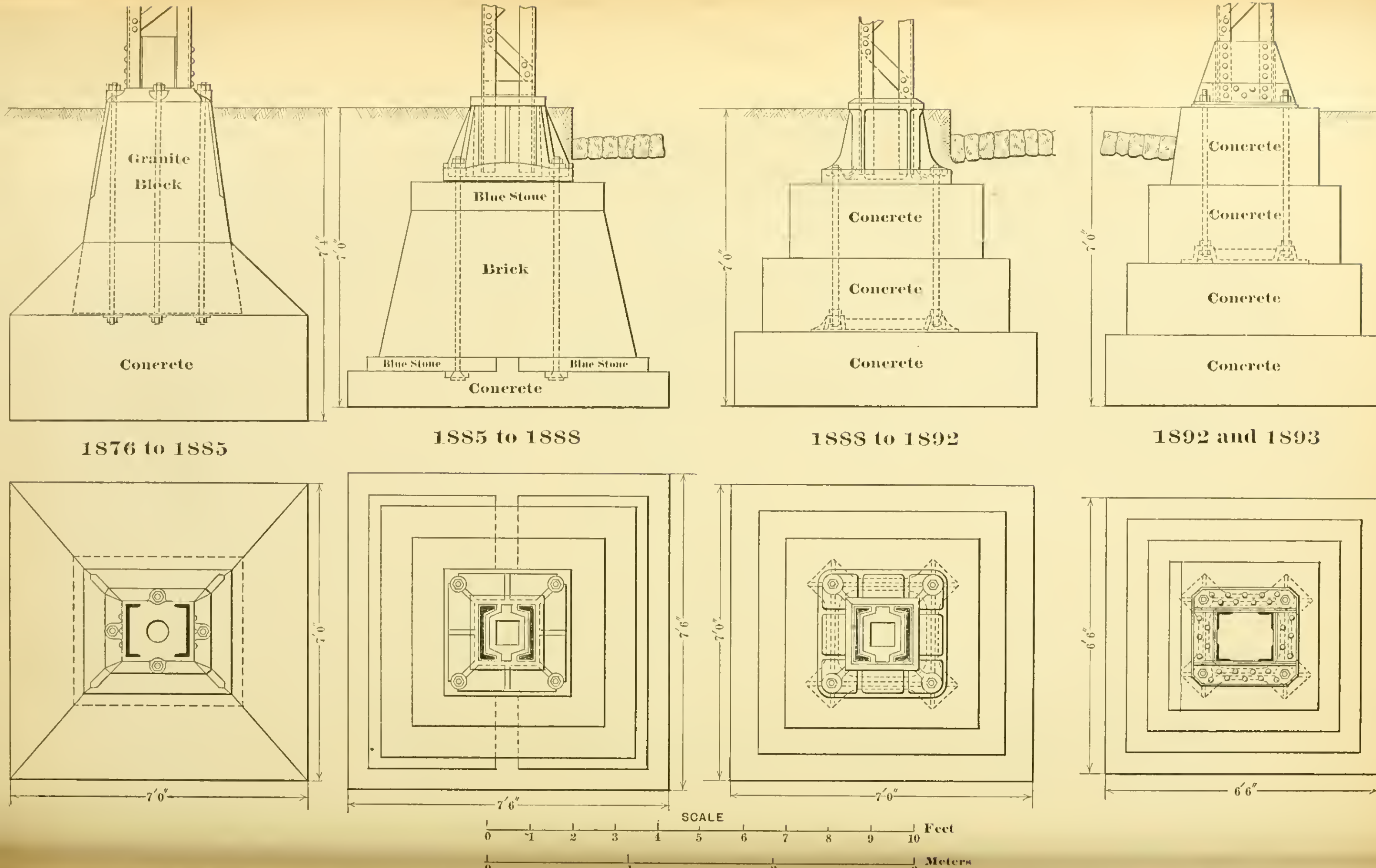
* Manuscript received Sept. 13, 1894.—*Secretary Ass'n. of Eng. Socs.*

schemes that had been proposed in Brooklyn, and it was not till 1885 that any portion of the present existing lines was completed and ready for operation. The first line built embraced four and one-half miles of structure, extending from the intersection of York and Washington Streets, through York Street and Hudson, Park, Grand and Lexington Avenues, to the intersection of Broadway and Gates Avenue. It was opened for business to this point in May, 1885. This line was extended through Broadway into Fulton Avenue to Schenck Avenue, in the latter part of 1885, completing the original line of the Brooklyn Elevated Railway, and embracing six and one-half miles of double-track structure.

In 1886, the Union Elevated Railway Company was organized. In rapid succession it built the Broadway, Myrtle Avenue, and the Fifth Avenue lines, which, after completion, were leased to the Brooklyn Elevated Railway Company. In 1892–'93, under the writer's supervision as Engineer of Construction, the Fifth Avenue line was extended through Thirty-eighth Street and Third Avenue to Sixty-seventh Street, a distance of 1 8 miles, and the Fulton Avenue line was extended through Fulton and Cresent Avenues to Cypress Hills Cemetery, a distance of 1.42 miles, making, with that formerly built, the 20 miles of double-track structure now operated by this company. This system, together with the 6.89 miles of elevated line owned and operated by the King's County Elevated Railway Company, comprises the entire rapid transit system of Brooklyn, unless the surface steam road of the Long Island Railway Co., in Atlantic Avenue, can be said to afford such facilities.

In 1891, that portion of the old Brooklyn structure in Park Avenue, and in Grand Avenue, north of Myrtle Avenue, was abandoned, and in 1893 it was entirely removed. Hence it is not shown in Fig. 1. It was located about a quarter of a mile north of, and parallel to, the structure in Myrtle Avenue, and hence it could not be profitably operated after the construction of the latter line.

The several types of foundations and superstructures which have been used during successive stages of development, are shown in Figs. 2, 3, and 4, with the dates when the several types of construction were used. It is difficult to conceive an adequate reason for adopting the first two types of foundations used, when the manifestly excessive cost and difficulties involved in their construction are considered, and when it is further considered that they were conceived and built within the period when a knowledge of better and cheaper methods and materials prevailed quite generally. The pure concrete construction was adopted in 1888, discarding the blue stone and the granite, but continuing the use of the base casting until 1892, when the present column base was



Granite
Block
Concrete
7′4″
7′0″
1876 to 1885
7′0″
7′0″
Blue Stone
Brick
Blue Stone
Blue Stone
Concrete
1885 to 1888
7′6″
7′6″
Concrete
Concrete
Concrete
7′0″
1888 to 1892
7′0″
7′0″
Concrete
Concrete
Concrete
Concrete
7′0″
1892 and 1893
6′6″
6′6″
SCALE
0 1 2 3 4 5 6 7 8 9 10 Feet
0 1 2 3 Meters

adopted. The base casting admits of a neater construction, but the superior anchorage and economy of construction offered by the present column base, outweigh this feature. There is nothing unusual or novel in the present type except, perhaps, the fact that the concrete is brought to the surface and the columns rest directly upon it; and the subsequent treatment of the exposed surfaces. After the erection of the iron work, the top surface of each foundation, and its faces for a depth of about six inches, were roughly pointed off and then finished with about one inch in thickness of a fine concrete, locally called "Kosmocrete," composed of the best imported Portland cement and finely crushed granite, a composition similar to that used in sidewalks in St. Louis. This work is very much cheaper than the cap stones generally used for such purpose, costing but $5.00 per foundation, by contract, and it was tested before its adoption. Thus far its use has been eminently successful. The foundation has stood the past winter without any evidences of failure from frost action, and it possesses a surprising tenacity in resisting abrasion by wheels of vehicles. The last stairway landings constructed were treated in the same way, and they are found to wear much less rapidly than the Hudson River blue stone heretofore used for that purpose. So far as the writer is advised, this is the first instance where this material has been used in such situations.

In the earlier history of the work the lattice girder, with all its inherent defects, was used. Fortunately for the Company, these defects were discovered early and none of these girders were built after 1885. The sections of the web members would have been ample if they could have been properly *welded* to the chords, but they were riveted instead, and the rivet holes were ignored. During the summer of 1893, a thorough examination of all the old structure was made, disclosing facts which are graphically set forth in Fig. 5, showing unit stresses far exceeding those admitted in good practice. Some of the old plate girders also were found to be much overstrained, but their reinforcement will be simple and cheap as compared with the treatment necessary for the lattice girders.

Prior to 1892, iron was used exclusively in all the structures built, but steel was introduced and used almost exclusively in the extensions built in 1892–'93. As seen in Fig. 4, stiffening angles were used with reckless extravagance on all plate girders built prior to 1888, being placed on each side of each longitudinal girder about five feet apart throughout their length, and having a filler plate under each, to bring them flush with the chord angles. Since 1888, they have been almost entirely omitted, and the result has been the very large saving of metal, shown by the appended table, without any reduction in the strength of the structure.

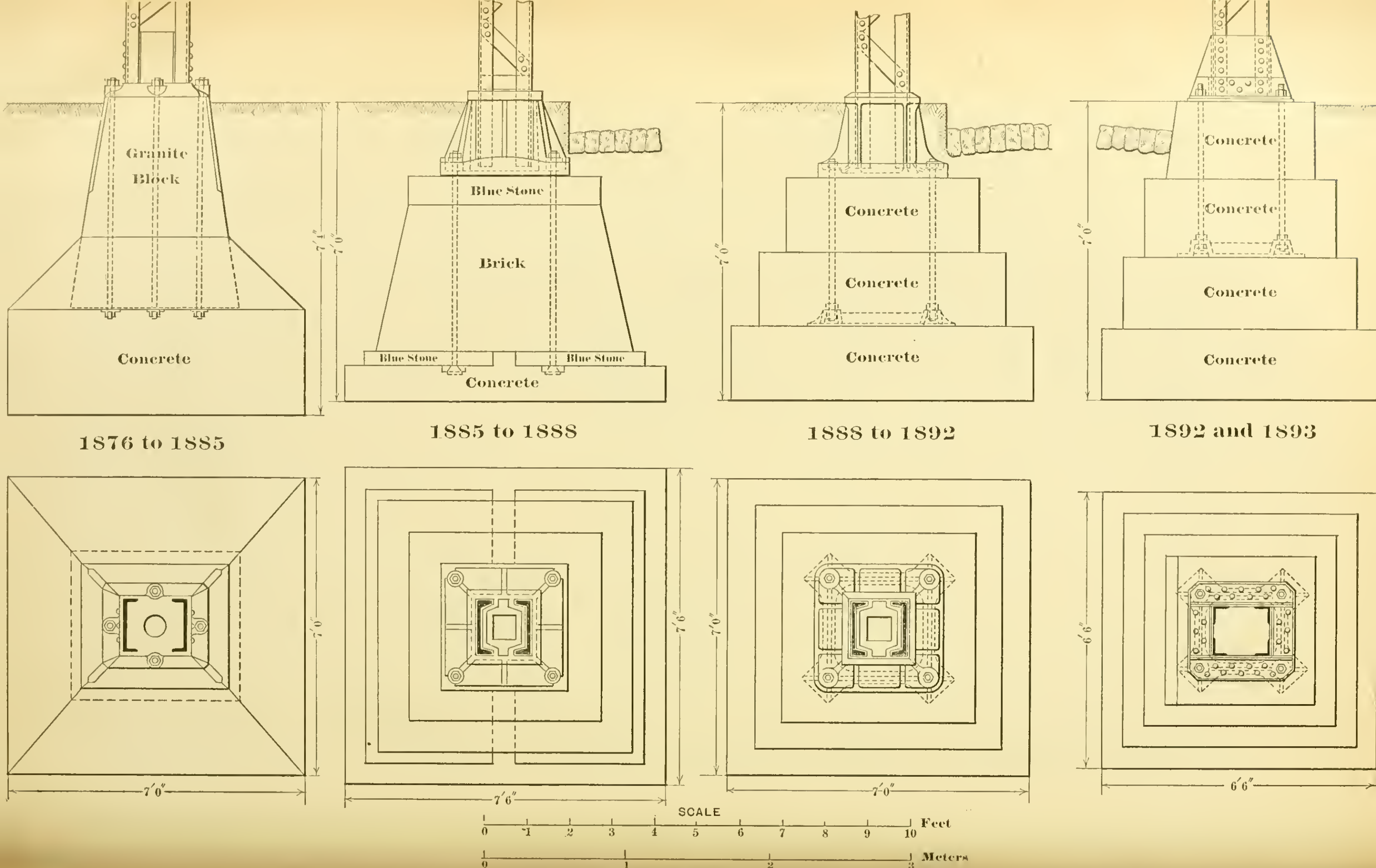


Fig. 2.—Types of Standard Foundations.

adopted. The base casting admits of a neater construction, but the superior anchorage and economy of construction offered by the present column base, outweigh this feature. There is nothing unusual or novel in the present type except, perhaps, the fact that the concrete is brought to the surface and the columns rest directly upon it; and the subsequent treatment of the exposed surfaces. After the erection of the iron work, the top surface of each foundation, and its faces for a depth of about six inches, were roughly pointed off and then finished with about one inch in thickness of a fine concrete, locally called "Kosmocrete," composed of the best imported Portland cement and finely crushed granite, a composition similar to that used in sidewalks in St. Louis. This work is very much cheaper than the cap stones generally used for such purpose, costing but $5.00 per foundation, by contract, and it was tested before its adoption. Thus far its use has been eminently successful. The foundation has stood the past winter without any evidences of failure from frost action, and it possesses a surprising tenacity in resisting abrasion by wheels of vehicles. The last stairway landings constructed were treated in the same way, and they are found to wear much less rapidly than the Hudson River blue stone heretofore used for that purpose. So far as the writer is advised, this is the first instance where this material has been used in such situations.

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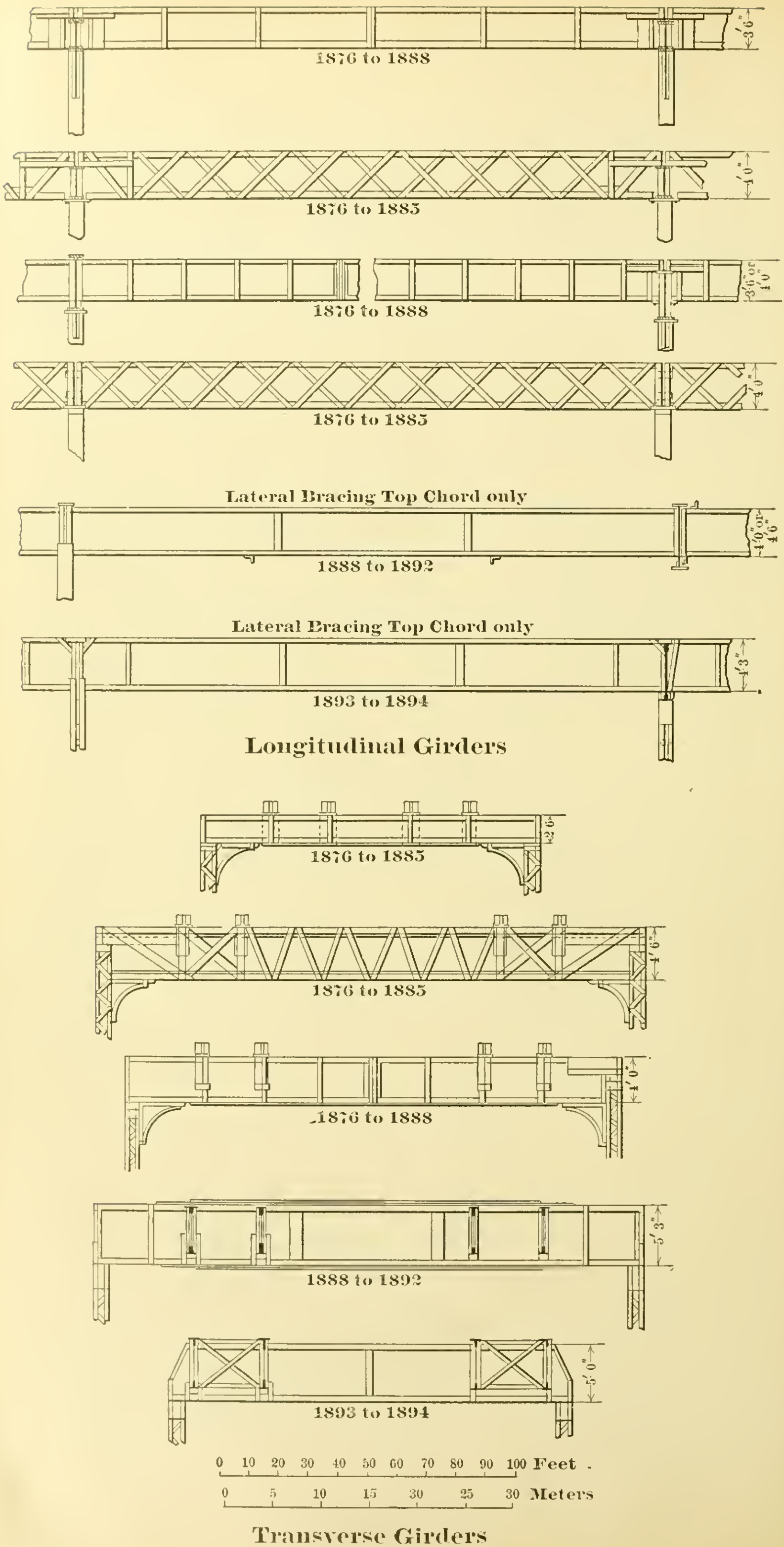


FIG. 4.—STANDARD GIRDERS.

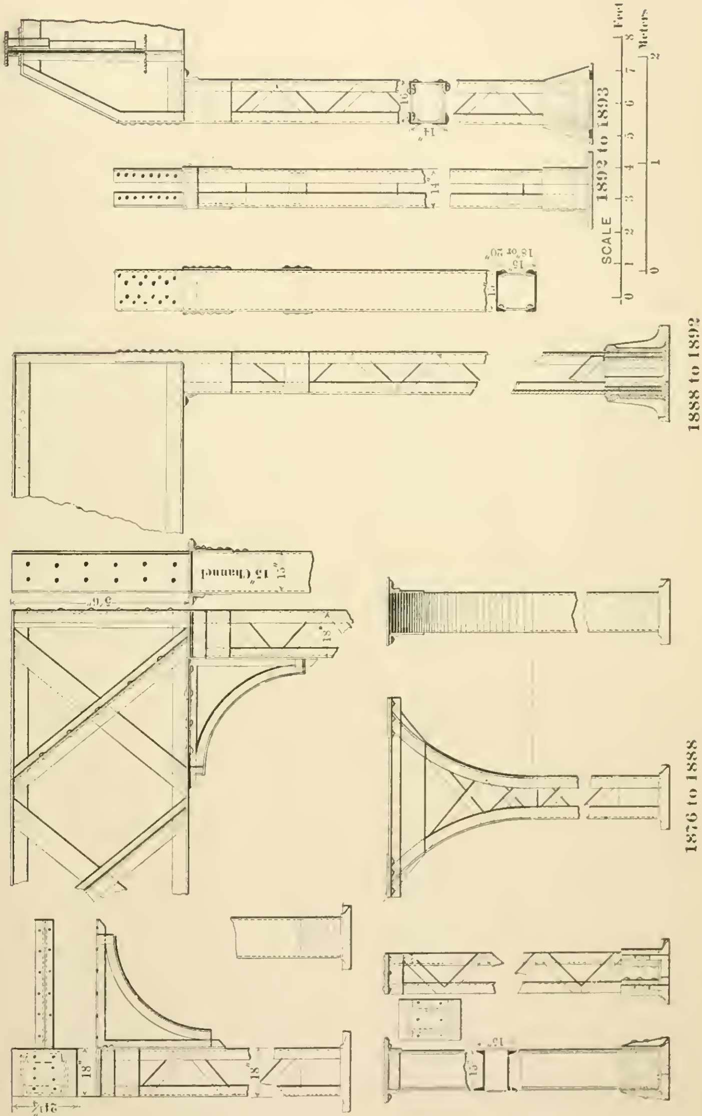


FIG. 3.—TYPES OF STANDARD COLUMNS.

LATTIEE GIRDERS NOS. 598 TO 719.

PLATE GIRDERS NOS. 760 TO 785.

FIG. 5.—STRESSES IN TRANSVERSE GIRDERS.

Table Showing Data from Three Periods of Construction.

	Built between		
	1885 and 1888.	1888 and 1891.	1892 and 1893.
Miles of structure built	5.6	5.4	3 22
Number of stations	14.	19.	9.
Total net tons of iron in structure	19,488	16,203	10,980
Average net tons per mile	3,473	3,001	3,055
Maximum tons per mile	3,578	3,566	3,287
Minimum tons per mile	2,907	2,842	2,824
Average total cost per mile	$542,441 00	$332,352 00	$297,599 00
Average cost of iron per ton	79 00	68 68	61 00
Average cost of each foundation	187 70	140 90	93 50

The last structure was built in 1892–'93, and was proportioned for heavier engine loads and for the use of iron ; but when steel was adopted the original sections were not changed. This structure has also a greater average height than any Brooklyn elevated railway heretofore built, some of it being 55 feet to base of rail, and it contains the first Brooklyn elevated railway columns proportioned to resist flexure, the uniform practice having been to allow 6,000 pounds per square inch in all columns for static load, and to ignore all bending stress. This latter practice, which seems to be fully justified by experience, was departed from, in the one instance cited, because of the unusual height of the structure and its exposure to the strong gales from New York Bay, near which it is located.

At one point on the Fifth Avenue extension, the right-of-way conditions warranted placing the two columns of one bent 16 feet 5 inches apart, center to center. The height was 55.24 feet to base of rail. The bent was on a curve of 175 feet radius, and carried one end of a span 91 feet long, on a grade of one per cent. These conditions necessarily involved very heavy construction. The two columns weighed about nine tons each and were anchored to the foundations by six 2-inch bolts. The transverse girder is 114 inches deep and is riveted to the columns through its entire depth. The three 91 feet girders, composing the long span, are each 90 inches deep and they weigh, respectively, 15, 17 and 19 tons. They were built and shipped each in one piece, and were hoisted into position by an erecting traveler having an iron boom 75 feet long. The stiffness expected from this construction has been fully realized. Under conditions producing maximum stresses, the structure at this point vibrates little, if any, more than at other points on tangent where the height is not half so great and where the columns are spread 45 feet.

The following additional data, relating to the last structure built,

may be of interest as illustrating recent results in elevated railway construction:

Length of structure built	3.22	miles.
Total cost per mile, including stations	$297,599	
Total cost of iron work per mile	184,423	
Total cost of foundations per mile, including bolts	18,649	
Total cost of double track per mile, including material and labor	43,248	
Total cost of stations per mile	38,819	
Total cost of engineering per mile	9,934	
Total quantity of concrete per mile in foundations	1,900	cubic yards.
Total quantity of iron per mile	3,055	net tons.
Total quantity of timber per mile in track	683,672	feet.
Average weight of steel per foot of structure	1,157	pounds.
Number of foundations per mile	200	
Percentage of engineering expense to total cost	3.35	per cent.

The maximum work of erection in 10 hours was 12 spans of 52 feet each, weighing 315 tons, and an average of 8 spans per day was easily maintained.

The above figures include about 2,800 lineal feet of third and cross-over tracks, and they are based upon the following cost of materials, viz.:

Portland cement, concrete	$ 7 00	per yard.
Excavation	50	per yard.
Steel in structure	61 00	per net ton.
Timber	20 00	per 1,000 feet.
Steel rails (85 per yard)	31 00	per gross ton.
Labor, laying track (single)	35	per foot.

It will be noted that the average span length was about 53 feet. While this is not the length of maximum economy in cost of construction, it is thought, from past experience, that it will be more economical than shorter spans in the matter of reducing damage to abutting property. With present prices, a span length of 30 feet would be the most economical in first cost, and would result in a saving of about 5 per cent., considering only the foundations and superstructure.

From a financial standpoint, perhaps the greatest error in design made in building the older roads, was that of placing the stations outside of the two tracks, instead of adopting the present practice of placing them between the tracks. The use of outside stations approximately doubles the first cost of stations, and the cost of station maintenance and station service. The following figures, based upon the actual cost of inter-track stations and of station service and maintenance, will best illustrate the facts involved. For the year 1893, the average cost of station service and maintenance was $2,400 per station, and the cost of new inter-track stations was about $11,000 each. Hence the following comparison, viz.:

Comparative Statement of Operating Expenses of the Manhattan, Kings County and Brooklyn Elevated Railroads for Fiscal Years Ending June 30th.

ITEM.	Manhattan. 1891. Passengers carried, 196,714,199. " per mile, 6,040,560. Length of road opr., 32.4 miles. No cars, 1,021. No. engines, 321.		Kings County. 1891. Passengers carried, 15,992,855. " per mile, 2,317,800. Length of road opr., 6.892 miles. No. cars, 130. No. engines, 42.		Kings County. 1892. Passengers carried, 17,357,932. " per mile 2,307,315. Length of road opr., 7.523 miles. No. cars, 130. No. engines, 43.		Brooklyn. 1891. Passengers carried, 34,424,708. " per mile, 2,037,000. Length of road opr., 16.91 miles. No. cars, 230. No. engines, 76.		Brooklyn. 1892. Passengers carried, 35,995,837. " per mile, 2,128,672. Length of road opr., 16.91 miles. No. cars, 230. No. engines, 76.		Brooklyn. 1893. Passengers carried, 38,110,376. " per mile, 2,253,716. Length of road opr., 16.91 miles. No. cars, 230. No. engines, 76.	
	Amount.	Remarks.	Amount.	Remarks.	Amount.	Remarks.	Amount.	Remarks.	Amount.	Remarks.	Amount.	Remarks.
Maintenance of Way and Structure.												
Repairs of track and structure	$419,959 88		$18,897 02		$19,819 36		$20,481 76		$32,353 19		$38,316 59	
Repairs of stations, shops, etc.	136,301 76	$17,223 per m.	5,570 53	$3,550 per m.	4,638 15	$3,252 per m.	7,255 00	$1,640 per m.	9,100 78	$2,405 per m.	13,032 29	$3,061 per m.
Other expenses, M. of W. & S.	1,770 80		. . . .		. . .		. . . .		289 27		425 30	
Total	$558,032 44		$24,467 55		$24,457 51		$27,736 76		$41,743 24		$51,774 18	
Maintenance of Equipment.												
Repairs of locomotives	$256,492 67	$800 per loco.	$16,937 97	$403 per loco.	$21,782 11	$506 per loco.	$33,990 97	$447 per loco.	$43,691 60	$575 per loco	$40,317 29	$530 per loco.
Repairs of cars	247,124 41	242 per car.	17,948 55	137 per car.	17,557 81	135 per car.	31,020 31	135 per car.	41,507 07	180 per car.	53,039 53	230 per car.
Repairs of machinery and tools	17,822 03		1,109 17		1,607 23		968 28		1,134 10		1,730 76	
Other expenses, M. of E.	103,589 59		6,889 49		7,318 28		7,797 74		7,940 93		11,847 72	
Total	$625,028 70		$42,885 18		$48,265 43		$73,777 30		$94,273 70		$106,935 30	
Conducting Transportation.												
Wages of conductors and guards	$656,824 89	$643 per car.	$53,287 62	$409 per car.	$54,466 90	$419 per car.	$97,671 94	$425 per car.	$100,623 67	$437 per car.	$ 99,343 85	$432 per car.
Wages of engineers and firemen	708,395 92	2,206 per loco.	92,707 88	2,207 per loco.	92,619 43	2,154 per loco.	199,760 96	2,628 per loco.	200,404 44	2,637 per loco.	205,180 83	2,699 per loco.
Fuel for locomotives	788,136 14		123,837 30		117,903 66		248,051 00		230,221 33		246,131 53	
Oil and waste	73,777 80		2,528 84		3,098 76		7,785 43		7,553 75		6,085 92	
Water supply	65,789 44	3,043 per loco.	6,005 33	3,632 per loco.	4,408 91	3,341 per loco.	9,959 85	3,680 per loco.	10,921 11	3,492 per loco.	12,661 38	3,703 per loco.
Other train expenses and supplies	49,272 79		20,185 08		18,262 95		13,860 82		16,707 83		16,585 73	
Wages of station agents, gatemen, etc.	494,405 26	6,074 per sta.	83,121 08	3,620 per sta.	82,121 90	3,581 per sta.	155,745 28	3,248 per sta.	158,208 69	3,316 per sta.	158,331 71	3,324 per sta.
Station supplies	84,737 63	(97)	10,992 79	(26)	10,982 33		6,638 17	(50)	7,608 96		7,893 11	
Wages of flagmen, switchmen, etc.	140,333 89	11,854 per m.	12,462 77	2,471 per m.	12,670 23	2,297 per m.	25,255 37	5,275 per m.	24,612 83	5,395 per m.	25,600 48	5,489 per m.
Other expenses, C. T.	244,668 87		4,572 29		4,605 25		63,947 95		66,616 33		67,225 84	
Total	$3,306,342 63		$409,700 98		$401,140 32		$828,676 77		$823,478 94		$845,040 38	
General Expenses.												
Salaries of officers and clerks	$183,904 47		$37,616 88		$36,472 00		18,274 09		$27,233 28		$32,217 55	
General office expenses and supplies	35,423 63		9,410 53		8,774 92		670 16		615 68		809 30	
Stationery and printing	53,554 45		4,965 83		5,189 27		5,361 45		5,680 43		6,746 94	
Advertising	3,131 37		14 04		17 00		1,872 85		721 70		444 80	
Legal expenses	92,189 87	90c per daily passenger per year.	13,959 86	$1.86 per daily passenger per year.	15,632 88	$1.81 per daily passenger per year.	13,248 08	62c per daily passenger per year.	14,031 54	72c per daily passenger per year.	16,574 05	84c per daily passenger per year.
Damage to property	1,488 44		230 48		21 60		794 81		437 65		915 08	
Damage to persons	63,774 21		3,186 85		300 00		6,687 51		7,941 34		14,434 74	
Telegraph maintenance and operation	2[illegible],78[illegible] 40		12,213 50		11,2[illegible]0 24		1 395 96		1.282 30		1,195 69	
Other general expenses	25,484 46		7,591 01		8,628 31		11,375 94		13,087 87		14,595 55	
Total	$485,737 30		$89,188 98		$86,296 22		$59,680 85		$71,031 79		$87,963 70	
Grand Total Operating Expenses	$4,975,141 07	Op. ex. 50$\frac{6}{10}$%	$[illegible]66,242 69	Op. ex. 70$\frac{8}{10}$%	$560,159 48	Op. ex. 64$\frac{6}{10}$%	$989,871 68	Op. ex. 56$\frac{98}{100}$%	$1,030,527 67	Op. ex. 56$\frac{98}{100}$%	$1,091,713 56	Op. ex. 56$\frac{53}{100}$%

[illegible]

	Inter-Track Station.	Outside Station.
Original cost	$11,000	$20,000
Capitalization of annual cost at 5 per cent. .	48,000	96,000
Totals	$59,000	$116,000

This indicates a saving of $57,000 in capital account, which could be expended in avoiding the use of outside stations, and, as there are, on an average, three stations per mile of structure, a sum equal to about 57 per cent. of the entire present cost per mile of structure, could, if necessary, be profitably expended in so designing the work as to admit of the use of inter-track stations.

The following table gives the contract prices for the several classes of work entering into the construction of the nine inter-track stations built in 1893, and these figures include every item of their cost, except the platform girders and their lateral bracing.

TABLE SHOWING DETAILS OF COST OF STATIONS.

Name of Station.	Carpenter Work.	Sheet Metal Work.	Painting and Decorating.	Plumbing Work.	Heating Apparatus.	Architectural Iron Work.	Total Cost.
Cleveland Street .	$3,095	$1,432	$409	$206	$225	$2,100	$7,467
Norwood Avenue .	3,024	1,445	415	206	221	2,100	7,411
Crescent Avenue .	3,124	1,445	415	206	221	2,100	7,511
Cypress Hills . . .	6,686	2,323	972	2,081	1,028	3,100	16,190
Fortieth Street . .	3,888	1,203	550	296	330	2,500	8,767
Forty-sixth Street .	3,578	926	540	296	295	2,200	7,835
Fifty-second Street.	3,578	926	540	296	295	2,200	7,835
Fifty-eighth Street.	3 578	926	540	296	295	2,200	7,835
Sixty-fifth Street .	7,200	3,470	850	2,150	845	2,900	17,415

The first four stations in the table and the last five were built under separate contracts, the former (except Cypress Hills) having one stairway each, while the latter have each two stairways to the street. Cypress Hills and Sixty-fifth Street are terminal stations, where the entire station platforms are covered by a canopy, and where, in addition to the usual station building for the use of passengers, there are other buildings on the opposite end of the platform, which contain a trainmen's waiting room, trainmen's water closet, oil and lamp room, signal tower and train dispatcher's office, all of which contribute to make up the largely increased cost of those two stations. At Fortieth Street the structure is 43 feet high and the station building is located under the tracks. The stations at Forty-sixth, Fifty-second and Fifty-eighth Streets are standard typical stations, being designed and built for entirely normal conditions.

The hot water system is employed to warm all these stations, and it has proved to be very successful. The heater is located in a sub-story under the station building. A loop of 1½ inches hot water pipes are run along with the supply and waste pipes from the station to the ground to prevent the latter from freezing in severe weather. Circulation of hot water is maintained in these pipes by taking the supply from an expansion tank placed in the top of the station, the return pipe going directly to the heater. At Sixty-fifth Street Station abundant circulation is maintained in three separate loops, which descend about 30 feet below the heater by taking the supply from a tank located in the top of the signal tower. It may be of interest to add that this work was undertaken and successfully accomplished in the face of adverse opinions expressed by most of the bidders on it, who maintained that the hot water could not be made to circulate below the level of the heater.

In the track first laid, the ties and guard timbers were all of 6-inch x 8-inch timber, the ties being laid with the 8-inch face on the girders, to which each was bolted by short hook bolts, and the four guard timbers were laid with the 6-inch face on the ties, to which they were bolted by ¾-inch bolts through every alternate tie, the nuts being counter-sunk in the timber and the counter-sink filled with cement mortar. The ties were spaced 22 inches apart on centers, and the rails weighed 60 pounds per yard. The foot-walks were supported on independent 6-inch x 6-inch timbers, which passed under both track rails. In 1888 the ties were made 7 inches x 8 inches, two outside guard timbers 7 inches x 8 inches and the two inside ones 6 inches x 6 inches. The outside guards were bolted to the girders by long ⅞-inch hook bolts through each alternate tie, the bolts having special hexagon nuts. The hook bolts also are of a special design, having square shanks to prevent them from turning in the timber. The inside guards are bolted to the remaining alternate ties by ¾-inch button-headed bolts having square shanks. The guard rails are not notched over the ties and the ties are not notched over the girders. The ties were spaced 16 inches on centers, and each fifth one was made long enough to carry the foot-walks, obviating the use of special timbers for that purpose. The 60-pound rail was retained until 1892, when an 85-pound rail was adopted, with rail-joints composed of angle bars 38 inches long, bolted by eight ⅞-inch track-bolts. This was the only change made in the track in 1892, except that the ties were spaced 15 inches on centers and the inside guard rails were spaced 6 inches from the track rails in lieu of 4 inches. The use of a heavier rail was adopted in order to secure greater wearing qualities and a broader and deeper head, and to obtain a broader base with the consequent reduction of the tendency to cut into the ties. The vertical motion permitted by the cutting rapidly

wears the spikes just under the head, so that in the older track many of the spikes had not enough section left to withstand the use of the claw-bar in drawing them. The increased lateral motion thus permitted also badly deranges the alignment and gauge.

The writer believes that an increase of economy in first cost and in cost of maintenance could be accomplished by omitting the two inside guard timbers, which experience has shown to be wholly superfluous, and by dressing and sizing all the timber. It is among the remotest probabilities that a derailment could occur on a straight piece of elevated railroad track, and it is only on such track that the inside timbers are used, a single steel guard rail being substituted for them on all curves, cross-over tracks and turn-outs where derailments are probable. Experience, covering a period of nine years in Brooklyn and more than twenty years in New York, lends substantial support to this theory and seems to warrant the omission of these two timbers, particularly when we consider the greater and ample security offered by the heavier outside timbers. Besides necessitating the provision and maintenance of additional perishable material, the inside guards decrease the life of the ties and increase the cost of labor involved in their renewal by preventing free access of air and sunlight, and by requiring the handling of this added material.

The writer's observations in connection with the laying of unsized ties have led him to the belief that it is not practicable to secure uniform bearing of the rails on the ties, or a full bearing of the ties on the girders by adzing the under sides of the ties, for track-laying is always done hurriedly. The consequent defects of track surface are, it is believed, largely responsible for the subsequent cutting of the ties by rails and the destruction of the spikes. If the top chords of the longitudinal girders are free from surface bends, the difficulties with the ties may be entirely obviated by sizing and dressing them in a machine, and it is believed that, independently of the resulting increase in the durability of the timber, the cost of this treatment would be well invested. It would also increase the rapidity of track-laying, which is by no means an inconsiderable feature.

Among the engineers who were connected with the Company prior to November, 1884, were Messrs. J. L. Nostrand, W. F. Bruff, Albert Lucius and Samuel H. Shreve in the order named. Mr. Shreve was succeeded in November, 1884, by Mr. George B. Cornell, who remained Chief Engineer until October, 1888, when he was succeeded by the present Chief Engineer, Mr. O. F. Nichols. The two gentlemen last named have designed and built 14.22 miles of the 20 miles of structure now operated by the Company.

ON THE COMPOSITION OF THE OHIO AND CANADIAN SULPHUR PETROLEUMS.

By Professor Charles F. Mabery, Member of the Civil Engineers' Club of Cleveland.

[Abstract of a paper read June 18, 1894.*]

Among the most familiar things in the every-day life of the present generation are the products obtained from petroleum. If iron carbides are the source of the world's supply of petroleum, as is maintained by the eminent Russian chemist, Mendelejeff, there need be little apprehension for the future; but if, as is ably set forth by geologists and by most chemists, petroleum was formed by the decay of vegetable and animal matter, under peculiar conditions which are not likely to be repeated within the limits of the present civilization, if at all, the present deposits, when they are once exhausted, will not be replenished.

The formation of petroleum from the remains of former vegetable life, as has been explained by Lesley, Newberry and other geologists seems to account for the presence of oil in certain fields. The decomposition of animal remains in the limestone formations as a source of petroleum was first suggested by the late Dr. T. Sterry Hunt. This view as to the mode of formation has been confirmed by recent developments within the sulphur petroleum fields, and especially within those of this State, by the thorough investigations of Professor Orton, who had the exceptional good fortune to begin his observations with the first development in the Ohio fields, and to have secured the aid and ready co-operation of those who controlled this oil territory. After many years of successful experience in the extensive fields of Pennsylvania, the oil men were slow to admit that other conditions could exist than those with which they were familiar. If oil flowed, it must come from the oil sands and from strata with a certain angle of inclination. Careful examination of the geological formations, however, soon afforded conclusive evidence that the Trenton limestone must be accepted as a source of abundant oil deposits. The formation of petroleum from animal remains has recently been rendered probable on chemical grounds by the preparation of the ordinary petroleum products from fish oil. In 1865 Warren and Storer discovered, in a hydrocarbon naphtha which they distilled from a lime soap made from menhaden oil, several series of hydrocarbons identical with those which Warren had

* Manuscript received August 17, 1894.—*Secretary, Ass'n of Eng. Socs.*

previously identified in Pennsylvania petroleum. Dr. Engler, of Carlsruhe, has recently submitted menhaden oil to distillation under high pressure, and has thus succeeded in obtaining the volatile hydrocarbons, the burning oil, and the heavier oils with paraffine, which resemble in all respects the corresponding products from petroleum.

The oil from the Trenton limestone is as peculiar in its composition and properties as in the mode of its occurrence. Indeed, it follows as a necessary consequence of its associations, that its properties should be quite unlike those of the oils from the oil sands of Pennsylvania, since these associations indicate an origin similar to that of the limestone itself, or at least animal remains, as its probable source.

Refined oils from Canadian petroleum were known in commerce as early as those from Pennsylvania petroleum. Production here early reached its maximum. In the Canadian Geological Report for 1863 a well is mentioned that yielded 2,000 barrels of oil in twenty-four hours. Previous to March, 1863, the total output from wells within a range of four square miles in the township of Enniskillen was 103,463 barrels. The daily production of single wells later amounted to 7,000 barrels.

In the early wells of the Ohio fields, the conditions presented for geological investigation were essentially different from what had hitherto been observed in the Pennsylvania oil regions. To Professor Orton we are indebted for complete accounts of the geological formations in the petroleum areas of Ohio, and of the character of the limestone from which petroleum is obtained. The surface strata of the Ohio rocks consist of the glacial drift above the coal measures, followed by a succession of shales and limestones, through the Devonian into the Upper and Lower Silurian. The Lower Silurian includes the Hudson River series, above the Utica shales and next in order the Trenton limestone. It is somewhat difficult to determine with accuracy the thickness of the Trenton limestone, since it is for the most part a nearly level formation, with few outcrops.

Professor Orton has given a very clear description of the conditions necessary for the formation and storage of petroleum. For the accumulation of petroleum in sufficient quantities for economic production, the essential conditions in the rock formations include a source, a reservoir and an impervious cover conforming to a predominating series of anticlinals more or less marked. It is well known that geological formations, when subjected to lateral compression, have assumed folds with elevations, more or less sharply defined, which are termed anticlinals, and with corresponding depressions, the synclinals. It has been found that oil wells are productive only when they penetrate the reservoir on the slope of an anticlinal near the summit. In the Pennsylvania oil fields the carboniferous shales constitute the source, and the oil-bearing

sands with their impervious cover form the reservoir. In the Ohio deposits the Trenton limestone constitutes both source and reservoir. Another essential condition is an adjustment of the anticlinal elevations suitable for the maintenance of a high pressure within the reservoir. In drilling for oil, the flow of oil is preceded by the escape of gas, and when the oil is exhausted there is usually a rush of salt water. The internal pressure is, therefore, accounted for by the geologists on hydrostatic principles; the lighter gas and the oil collect in the anticlinal above the salt water, which exerts a pressure by filling the reservoir on an incline of greater elevation. There can, of course, be no flow of oil, or of gas, until all the overlying strata have been perforated and the reservoir is penetrated. Ordinarily, oil wells in Ohio must be sunk, at least, to a depth of 1,000 to 1,500 feet.

During the formation of the limestone or subsequently, the decomposition of organic matter, perhaps with the aid of heat and pressure, resulted in the production of petroleum apparently without distillation. An impervious shale, formed above the limestone by processes of deposition and hardening, furnished the cover. Subsequent elevations and depressions of the strata caused those final conditions of arrangement and of pressure which render petroleum deposits so easily accessible to the present generation. These changes have required countless ages for their consummation, and mankind will have the benefit of the petroleum supply so long as the internal pressure is sufficient to cause the oil to collect in appreciable quantities.

Oil is widely distributed in the Ohio shales and limestones. It has been estimated that the waterlime stratum contains not less than one-tenth of one per cent. Accepting the probable thickness of the waterlime as 500 feet, the quantity of petroleum contained in it would exceed 2,500,000 barrels to the square mile, or in one hundred square miles the quantity of oil would equal 261,000,000 barrels, the entire production in the great oil fields of Pennsylvania and New York to January, 1885. (Orton, U. S. Geological Survey, 1886–87, p. 507.) Yet this vast quantity of oil is of no value since it cannot be economically collected. Another important feature of the anticlinal system in Ohio, as demonstrated by Orton, is the form of the elevations. The anticlinal elevations are never abrupt; they are in the form of low terraces, and their outline is always evident in the productive oil and gas fields.

The storage of oil in considerable quantity within the limestone would seem to be impossible on account of its compact structure. The conditions are quite unlike those in the porous oil sands of Pennsylvania. But, after showing that the Trenton limestone does serve as a reservoir, Orton has demonstrated that it has the requisite porosity, and that this is due to the presence of magnesium carbonate, which is invariably

found in large quantities in the oil-bearing limestone strata. In other words, the limestone which serves as the reservoir is dolomitic, and its porosity depends upon its composition.

In general, the same conditions of structure are found in the Canadian oil fields as in those of Ohio, although they differ essentially in details. Here also, limestone serves as the source and as the reservoir, although it is of a different formation. The oil deposits are nearer the surface, within a depth usually of less than 500 feet. The flow of oil from individual wells is less than that from the Ohio wells; but in the earlier history of these wells the flow was in some instances very large.

The principal oil fields of Canada include that of Petrolia, about 27 square miles, and the adjacent territory of Oil Springs, about two square miles in area. Each of these fields is located on a distinctly outlined anticlinal, and they are separated by a synclinal yielding no oil.

Petroleum has been known in all ages. The Egyptians used it in the process of embalming. It was early known to the Chinese and to the ancient Greeks and Romans, and it was first discovered by white men in New York in 1769. The Indians recognized its medicinal value. The first attempts toward refining petroleum were made early in the present century when the price was $20 per gallon. The government soon became dissatisfied with the ineffectual attempts to utilize the oil, and sixty years ago the oil territory was sold for a trifling sum to private individuals. The development of the oil fields oi this country during the past thirty years has become familiar history. Fifty years ago attempts were made to separate the constituents of petroleum by distillation; but the means for such work were then so inadequate that little was accomplished. In 1862, two French chemists, Pelouze and Cahours, made the first attempt toward a systematic separation of the hydrocarbons contained in petroleum, with results which were highly meritorious, in view of the limited appliances for fractional distillation then known. But, unfortunately, the composition of petroleum is even now represented in chemical literature by a series of hydrocarbons $C_n H_{2n+2}$ homologous with marsh gas, which includes all the higher constituents, even the paraffine oils, which those chemists described, and which, without adequate evidence, have been designated by Watts as the paraffine hydrocarbons. Certain corrections in the observations of Pelouze and Cahours were made by Schorlemmer, and by Warren, who demonstrated, by the most thorough course of fractional distillation that was ever undertaken, that below 151°, Pennsylvania petroleum consists mainly of two series of hydrocarbons. The members of one of the series discovered by Warren boil approximately at 0°, 30°, 60°, 90°, etc., and those of his other series boil at 8°, 38°, 68°, 98°, etc. Besides establishing the presence of the two series below 150°, the results

of Warren demonstrated that the series $C_n H_{2n+2}$ terminates at this point, and that the portions with higher boiling points have the composition represented by the general formula $C_n H_{2n}$. Of other bodies contained in petroleum, the aromatic hydrocarbons, benzol, toluol, etc., have been recognized, and the Caucasus oils have been found by Markownikoff to contain in large quantity the naphtene series $C_n H_{2n}$.

In 1885, soon after the first wells were drilled at Lima, in an examination I was called upon to make for parties who were interested in this oil territory, the peculiar behavior of the oil during distillation was observed, and the presence of large quantities of sulphur. Further study of the oil was soon undertaken, more especially with reference to the nature of the sulphur compounds; and this study has occupied my attention at intervals ever since, until last autumn, when other series of compounds were included that had appeared in the separation of the sulphur derivatives. With the impression, conveyed by accounts received of the Canadian oil, that it, too, might prove to be interesting, I procured quantities of the crude oil and of the partially refined products, and it was soon found that it was even more promising than the Ohio oil. This investigation seemed especially inviting, since nothing whatever, except our own results, had been published on the Ohio sulphur oil, and scarcely anything on the Canadian oil relating to its composition. Upon examining critically the literature of American petroleums, I was impressed with the dearth of results that could be relied upon as affording accurate information, especially concerning the constituents with high boiling points.

Recognizing the need of further study of American petroleums in general, and of a complete examination of the sulphur oils in particular, I undertook such an examination of the Ohio and Canadian oils. European chemists have labored under certain disadvantages in their work on American oils, being so far removed from an abundant supply of products. This difficulty does not exist in Cleveland, and we have been most generously aided by oil firms and refiners, who have supplied whatever products were needed, and have placed at our disposal facilities available only where oils are refined on a large scale. This advantage, together with the aid of the appliances in the chemical laboratory of the Case School of Applied Science, which is well equipped for such investigations, has made possible the great amount of work already accomplished.

The lines of study include the separation and identification of the series of hydrocarbons homologous with marsh gas, the series of sulphur compounds, the aromatic hydrocarbons, the nitrogen compounds, the oxygen compounds, the unsaturated hydrocarbons, and any other substances that may appear in the progress of the investigation.

The only method known for the separation of the constituents of petroleum is that of fractional distillation. When water is boiled and a thermometer is inserted into the vapor, the temperature remains constant until all the water has been converted into steam. A definite boiling point is a characteristic property of every substance that is volatile without decomposition. In mixtures of substances with different boiling points it is practically impossible to separate completely the constituents, since every substance exerts a certain vapor tension below its boiling point and the more volatile substances remain dissolved to a certain extent in the less volatile portion. On this account the separation of individual constituents from such complex mixtures as petroleum, is exceedingly tedious. The most efficient forms of apparatus for fractional separation are the Hempel column and the Warren condenser. To avoid serious decomposition in the distillation of Ohio and Canadian oils, all distillations of crude oils have been conducted *in vacuo*, with a special form of apparatus devised for this purpose. The satisfactory results thus obtained depend upon the exclusion of air as well as upon the diminished temperature at which the distillates are collected.

The products which have occupied our attention include crude Ohio and Canadian oils, crude distillates from the refinery, and oils dissolved by sulphuric acid in refining. We have succeeded in proving the presence in the crude oils of a series of alkyl sulphides homologous with methyl sulphide, and of several members of other series of apparently unsaturated hydrocarbons. We have fractioned very thoroughly *in vacuo* 15 gallons of crude Canada oil, 10 gallons of crude Ohio oil, 30 gallons of sulphur oil from sulphuric acid extract, and, under atmospheric pressure, various smaller portions of crude distillates. From the products thus obtained nearly all the members in the series of hydrocarbons homologous with methane below 151°, hitherto recognized in petroleum, have been identified, and particular attention has been given to certain doubtful members of the series. In both the Ohio and the Canadian oils we have proved the presence of the aromatic hydrocarbons, benzol, toluol, the xylols and hexahydroisoxylol. Above 150° we have collected, without serious decomposition, fractions within 5° up to 350° *in vacuo* (nearly 500° atmospheric pressure). These products are reserved for later study.

For valuable aid in what has been accomplished I am indebted to my associates, Professor Smith and Messrs. Quayle and W. G. King, instructors in this laboratory; to Messrs. Hudson and W. H. King, students, and to my assistants, Messrs. Cleveland, Little and Giessen. I should also acknowledge my obligation for pecuniary aid, which has been granted by the American Academy of Arts and Sciences from the C. M.

Warren fund. A detailed account of these results will soon appear in the Proceedings of the American Academy.

DISCUSSION.

Prof. J. W. Langley.—This paper is one of extreme interest. No one but a chemist can appreciate the very large amount of labor which is involved in this distillation and the tediousness attendant upon it. It is essentially a chemical paper, but it illustrates how nearly chemistry may approximate to some lines of engineering. When we consider the large number of compounds found in oil, and remember that they result from action between only three elements—carbon, hydrogen and sulphur—we see how enormously complex are the forces which are at work to form these deposits. I should liken the labors of a chemist making this kind of analysis, and picking out these compounds, to those of an engineer required to determine every possible stress in a bridge, to select all the particles having a certain given stress and to leave them standing as a skeleton bridge sustaining that stress throughout. If such a thing were possible he could develop a large number of skeletons, no two of which would be alike. Similarly, out of the black mass of the oil the chemist isolates these compounds. I desire to express my personal pleasure in Dr. Mabery's work, and in this I am sure all the members here will bear me out.

Prof. E. W. Morley.—It is now generally conceded that Germany stands first in the line of chemical work accomplished. It is to Germany we look for our models, and what strikes me most impressively in the work of Dr. Mabery, a work with which I love to keep myself somewhat familiar, is the fact that, as regards the thoroughness, scope and a profound knowledge of the matter in hand, and of the thousand things tributary to it, he has undertaken the work like a German. I think we should be very grateful that there are a few men in this country who do work with that German thoroughness and with that breadth of touch.

The President.—I was much impressed with the great variation in the temperatures observed. If I remember rightly, the Doctor said that one sample was taken at 8° and another at 450°.

Dr. Mabery.—The 8° observed was at atmospheric pressure.

The President.—I did not suppose any petroleum could stand such heat as 450°, which is about red heat.

Mr. A. R. Brown.—I understand that when distillation at atmospheric pressure requires so high a temperature as to decompose the hydrocarbon, distillation in a vacuum is resorted to, in order to prevent

this decomposition; but I would ask whether the prevention depends upon the relief of the pressure and the consequent reduction of the distilling point, or upon the exclusion of the oxygen of the air.

Prof. Mabery.—Decomposition is prevented, both by reduction in boiling points, and by exclusion of air. The highest temperature noted *in vacuo* was 350°, equivalent to at least 450°, atmospheric pressure. Without diminished pressure, cracking and carbonization would doubtless soon have taken place. In distillations in presence of air, sulphur is invariably observed, indicating certain decomposition that cannot be wholly controlled, even *in vacuo*. We conducted a distillation under such conditions that the escaping sulphur could be determined. Three-fourths of the sulphur could be accounted for, leaving one-fourth that was evolved as sulphur and in a gaseous form. In the refinery, contact of the hot distillates with air is sometimes avoided by allowing the condensing tube to dip under water.

Mr. Brown.—Speaking of the tapping of the limestone rocks, do I understand that the oil is obtained only at the highest points of the anticlinals? Or does your remark apply merely to the upward slopes towards the anticlinals?

Prof. Mabery.—The anticlinals of Ohio and Canada are low terraces in which oil collects in the upper portions over the salt water

Mr. N. B. Wood.—During the winter I had occasion to burn oil continuously in a lamp, and I noticed on the chimney quite a heavy deposit of what I took to be chloride of ammonia or sal ammoniac. The question was: how the ammonia got there. It is probably present in distilled oil. Its presence shows the great difficulty of obtaining any of these substances purely by distillation.

Prof. Mabery.—The oils contain nitrogen which is evolved as ammonia. All these oils, so far as we have examined them, contain nitrogen, and deposits on chimneys may be caused by ammonic sulphate. Ammonia is sometimes used in refining. The sulphur escapes, at least in part, as sulphuric acid. Sodic sulphate may not be entirely removed in refining. Sometimes the deposit is dark in color, probably due to carbon. In a burning lamp, if the adjustment is not perfect, a trace of carbon may escape and cause a dark deposit. Then the composition of the refined oil is somewhat uncertain. The subject of cracking under high temperatures in refining has received very little attention. We have some experiments in progress to ascertain more fully what takes place in these decompositions.

Prof. Morley.—In further answer to Mr. Wood's question, I would say that there is present, in the air passing through the chimney of the lamp, enough ammonia to combine with the sulphuric acid produced by the oxidation of the sulphur of the oil, and thus to form

sulphate of ammonia. The white stains on brickwork, which are so annoying to architects, are sometimes due to the formation of alum. The sulphuric acid produced by combustion combines with ammonia existing in the air to produce ammonium sulphate and this, in combination with alum (aluminum sulphate) present in the stone or brick or mortar, produces these white incrustations. Some of these incrustations are due to other causes. I heard it once said that this alum was potassium sulphate, whereas it is ammonium sulphate. This deposit on the lamp chimney is interesting as a production in which two elements take part. I do not think there is enough nitrogen in the oil to be given off as ammonia. This coating varies in color. The difference in color is due to the concurrent decomposition of more or less carbon. Imperfect combustion of oil would coat that ammonium sulphate with more or less carbon.

Mr. M. E. Rawson.—Has there been any material change in the distillation of petroleum within ten or twenty years? Are they making many advances?

Prof. Mabery.—In principle there has been no essential change. Continuous distillation has been tried, but has not proved successful in this country. The stills are practically the same as those used twenty years ago. In the refining of Pennsylvania oils, treatment with sulphuric acid and with caustic soda, and bleaching in the sunlight, are chiefly used. Many patents have been issued for the removal of sulphur from oil. I devised a method in which I treated the sulphur with chloride of mercury. I mentioned the method in a paper four years ago, and in three months thereafter a patent was issued to an enterprising American for the same treatment. I had thought of applying for a patent, but found that the removal of the sulphur contained in 300 barrels of oil would cost $2,300, or nearly $8 per barrel, and inasmuch as oil is sold at 10 cents per gallon, this method could not be applied on a commercial scale.

When certain residues from the sulphur oils are treated with nitric acid they develope a beautiful red color. I believe some patents have been issued on colors made by such treatment.

Mr. Barber.—I would ask whether the Lima oil of Ohio is called sulphur oil, to distinguish it from the Pennsylvania oil?

Prof. Mabery.—I have myself applied that term to oils from the limestones of Ohio and Canada. One per cent. of sulphur, when referred to the sulphur compounds, is equivalent to at least five per cent. of the latter. Some Ohio oils are practically free from sulphur. Kentucky, Texas and California oils contain much sulphur, and I propose to include them in my examination.

STREET GRADES AND INTERSECTIONS.

By William B. Fuller, Member of the Boston Society of Civil Engineers.

[Read April 18, 1894.*]

One of the first problems to confront a municipal engineer is that of the establishment of the longitudinal grades of the city's streets. At first sight this appears a very easy matter, but, as we study it, many modifying features appear.

There is, first, the necessity of balancing, as nearly as may be, the cuts and fills, so that the first cost may be low; next, the consideration of surface drainage, in order that the water may be not directed in excess to any one spot, or made to discharge in a dry run which may be obliterated by private improvements and thus force the regrading of the street or the building of an expensive drain; next, the grades should be so arranged as to do away with deep cuts for the sewers which may become necessary under the street surface, and care should be taken that the street surface is far enough above the general drainage level to provide proper cellars. All of this, as well as the need of following the natural surface, as nearly as may be, in order to reduce claims for damages from abutting property owners, constitutes a study of what we may call the first cost of construction.

There are, however, other factors which are frequently overlooked as being of minor importance, although in a term of years they far exceed in importance almost any considerations of first cost. One of these is the cost of maintenance of the roadway. This cost (owing to the scour of water, the pull of horses' hoofs, and the increased friction of wheels when brakes are used), increases as the grade increases. If, however, proper road surfaces are selected in construction, this increase can be reduced to a negligible amount.

Another factor, and one of vital importance, is the cost of operation of a grade. This cost is a direct money loss, and one which increases with each year's increase of traffic and with each improvement of the road surface. Hence, a grade is properly determined only when the sum of the first cost, and of the capitalized cost of maintenance and of operation is at a minimum, and should never be tolerated unless the capitalized extra cost of operation is less than the cost of changing to better conditions.

*Manuscript received November 18, 1894.—*Secretary Ass'n of Eng. Socs.*

The cost of operation of a grade is dependent on many conditions, the principal of which are as follows:

First: The resistance to traffic on a level road. This resistance depends on the kind of vehicle, its velocity, the material of the road surface, and the condition in which this surface is kept. It has been determined by experiment under almost all conditions, and is found to vary from one-half of one per cent. of the load upon iron to about four per cent. upon a common gravel road, or to about twenty per cent. in loose sand. A compilation of the results of many of these experiments has been made by Rudolph Hering, M. A. S. C. E., and can be found in *The Engineering Record* for 1890, volume 21, page 122.

Second: The resistance directly due to the grade of the road. This resistance is equal to the load multiplied by the sine of the angle of inclination, or practically the load multiplied by the per cent. of grade.

Third: The wear on harness, vehicle and horse. This wear is represented by the average daily cost of vehicle and horse, and may be assumed to vary in direct proportion with the other resistances, although there is, perhaps, an excess of wear caused by the use of brakes in descending grades, when such grades are steeper than one and one-half times the percentage due to resistance to traffic on a level road of similar surface.

Fourth: The effect of grade on time of travel. The time required to haul a load up any usual grade exceeding 3 per cent. can be roughly assumed as the time on a level road multiplied by one-third of the percentage of grade.

Fifth: The difficulty of obtaining a foothold for horses on sloping surfaces. This can be determined only by experiment. Many classes of pavements are, on this account, unfit for use on steep grades.

Practical experience has demonstrated that there is not much difference in effect between level roads and those having grades not exceeding 3 per cent., unless such grades are very long or have an unusually good or well-kept road surface. As the force of gravity is constant, while the resistance to traction varies with the road surface, it follows that steeper grades are admissible on roads having surfaces of high resistance than on those of low resistance. For example, with asphalt surfaces having a resistance of $\frac{3}{5}$ of 1 per cent., a grade of 10 per cent. would make the total resistance $10\frac{3}{5}$ per cent., or allow of only $\frac{1}{5}$ of a full load to be drawn on the grade, assuming that a horse may exert twice his normal force for a short time when walking up such a grade. With a gravel surface having a resistance of 4 per cent., a 10 per cent. grade would produce a total resistance of 14 per cent., or, assuming the same conditions as above, the horse could draw $\frac{4}{7}$ of a full load. In practice, owing to the increased slipperiness and want of foot-

hold on surfaces of small resistance, the variation would be still greater than shown by the example.

From the above assumptions and data, we can derive a formula, which will represent approximately the capitalized cost of a grade:

Let t = percentage of resistance due to traction on level surface.
" g = percentage of resistance due to inclination of grade.
" n = number of full one-horse loads per day.
" h = capitalized cost of horse, harness and vehicle.

Then capitalized cost of grade $= \frac{(g - t)}{2t} n. h.$, and the amount which can be economically spent in reducing to a lower grade is $\frac{(g - g')}{2t} n. h.$ where g' = percentage of resistance due to inclination of lowest grade.

Of course, there are many cases where the grade which can be adopted is determined by other considerations than that of least cost at the end of a term of years. Where this is the case, provision should be made to carry out the proper work in the future with as little extra expense as possible. The effects of heavy grades on a railroad are easily seen in the increased cost of operation, and the same consideration applies as well, although in a less degree, to the grades of our city streets.

The minimum grade is limited only by the necessity for drainage, and should not be less than one half of one per cent., unless the road surface is very permeable, when the grade may be level. For minimum grades it is customary to make the axis of the road level and to obtain the grade by varying the depth of the gutter at the curb.

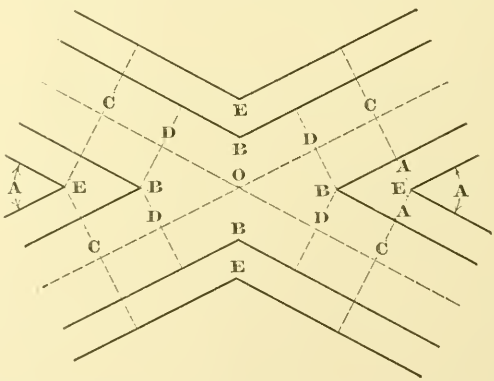
Transverse grades, or the crown of road surfaces, are also introduced merely for drainage, and should only be sufficient to effect this drainage. They are, therefore, generally determined by experiences with the particular class of road surface under consideration. Smooth, impenetrable surfaces, like asphalt, with unyielding foundations require but a slight crown, say one per cent., while other surfaces, like gravel, subject to ruts and to rapid and uneven wear, require much more—often as high as 4 per cent. On longitudinal grades, where the road surface is easily worn by water, the crown should, if possible, be sufficient to cause water to flow towards the gutters in a direction forming an angle of about 45 degrees, with the axis of the road, and not follow ruts, to the detriment of the road surface. A transverse slope, making one curb higher than the other, is sometimes given to a road to save first cost. It is rarely justifiable, and in no case should exceed 3 per cent.; but when used to relieve the grade of intersecting streets, it becomes of much value.

Street intersections properly come under the head of grades, and

when well planned, aid very materially in preventing the congestion of traffic. When intersecting streets cross at right angles and both have grades less than 3 per cent., there is no especial difficulty, the ordinary way being to carry the grades unbroken across the intersection. Streets with intersections at an acute angle with wide sidewalks and roadways and grades exceeding 3 per cent., require considerable study and practical experience for a satisfactory solution. I present here two formulæ which have been of considerable assistance to me in calculating such work. The first formula is for rectangular intersections, and can be found in *The Engineering Record*, volume 22, page 216.

The second formula is for oblique angle intersections, and is a follows:

For convenience call one of the intersecting streets "street," the other "avenue." Let $g =$ the maximum allowable percentage of transverse slope of sidewalk, $r =$ maximum allowable percentage of transverse slope of roadway. (In my own practice I assume $g = 6.0$, $r = 3.0$.) $A =$ acute angle of intersection of centre lines of streets. Let the grade from D to $D = a$ percentage, and that from D to $C = b$ percentage. Then:



To obtain the steepest per cent. of grade with which the "street" can cross the intersection

$$\left.\begin{aligned} \text{make } a &= r\,(\text{cosec. } A + \text{cot. } A) \\ b &= g\,(\text{cosec. } A + \text{cot. } A) \end{aligned}\right\} \quad (1)$$

To favor the "street" and "avenue" equally when the grade are to be in opposite directions

$$\left.\begin{aligned} \text{make } a &= r\,(\text{cosec. } A - \text{cot. } A) \\ b &= g\,(\text{cosec. } A - \text{cot. } A) \end{aligned}\right\} \quad (2)$$

To have the "avenue" crossing level

$$\left.\begin{aligned} \text{make } a &= r \tan A \\ b &= g \tan A \end{aligned}\right\} \quad (3)$$

Having fixed the percentages, a and b, of grades on the "street" somewhere within the limits as above, the percentage of grades on the "avenue" can be varied only as follows:

The maximum grades of the "avenue" crossing become

from D to C, $(b \cos. A + g \sin. A)$, (4)
from D to D, $(a \cos. A + r \sin. A)$, (5)

and the minimum grades become

from D to C, $(b \cos. A - g \sin. A)$, (6)
from D to D, $(a \cos. A - r \sin. A)$, (7)

With the "street" grades fixed, the "avenue" grades can vary only between the above limits. When grades between those given by Formulæ (4) and (6) are chosen, a break must be made at the two points D, and the grade from D to D must be made to conform to (5) and (7). When grades between those given by Formulæ (5) and (7) are chosen, the "avenue" grade can be continued unbroken across the "street."

EXAMPLE.

Intersection angle of crossing $= 40$ degrees. Assume $g = 6.0$, $r = 3.0$, and find cosec. $A = 1.55$, cot. $A = 1.19$, tan. $A = 0.84$, cos. $A = 0.77$, sin. $A = 0.64$. Substituting in the above formulæ we have

(1) $a = 8.2$ per cent. (2) $a = 1.1$ per cent. (3) $a = 2.5$ per cent.
$b = 16.4$ per cent. $b = 2.2$ per cent. $b = 5.0$ per cent.

We then see at a glance, Formula (1), that with both grades in the same direction, the steepest grade we can have on the "street" from C to D is 16.4 per cent., and from D to D, 8.2 per cent. If the grades are in opposite directions, and if the two streets are of equal importance, Formula (2), the grade D to C would not exceed 2.2 per cent., and from D to D, 1.1 per cent.

If the grades are in opposite directions, and if we favor the "street" as much as possible, Formula (3), the grade from D to C becomes 5.0 per cent., and from D to D, 2.5 per cent.

Having fixed the "street" grades a and b somewhere within the above limits, as appears the best for each special case, the "avenue" grades become also fixed within certain limits. Suppose the grades to have been fixed $a = 8.2$, $b = 10$, the maximum grades then become Formula (4) $= 11.5$; (5) $= 8.1$; (6) $= 3.9$; (7) $= 4.3$. That is, the grade DC can vary between 11.5 per cent. and 3.9 per cent., and the grade DD can vary between 8.1 per cent. and 4.3 per cent.

Other values of a and b would of course give other results, but the use of the formula is to indicate at a glance the limits of a good design, within which limits many variations can be made, but outside of which the intersection would prove a disappointment.

It will be noticed that when A becomes 90 degrees, this formula reduces to the much simpler one given first for right angle intersections.

The foregoing line of investigation is only applicable to city streets destined to have curbstones and sidewalks on each side. I find that the common way of laying out intersections in suburban districts is to neglect any consideration of sidewalks, to plot a profile of the curb lines of the street and connect with a vertical curve. When the district expands and sidewalks are demanded it almost invariably happens on grades exceeding 6 per cent. that sidewalk slopes are excessive, and much regrading must be done to make even a tolerable intersection.

THE CONSTRUCTION OF A SEA WALL AT FORT TAYLOR, KEY WEST, FLORIDA.

By Lieutenant-Colonel Jared A. Smith, Member of the Civil Engineers' Club of Cleveland.

[Read October 9, 1894.]

In 1873 and subsequent years, I was in charge of the construction department at Fort Taylor at the Dry Tortugas, Fla. One day in the winter of 1873–4, at Fort Jefferson, I observed in the ditch what seemed to be an immense pudding-stone, or boulder. It was a singular stone, and I ascertained from the overseer that when Fort Jefferson was being constructed, he had a coffer-dam inclosing part of the wall, and a break occurred in the dam through which the water begun rushing. The dam had been filled with sand and mud, which washed out very rapidly. The overseer had at that time several large beds covered with concrete, all thoroughly mixed, but not moistened, and this material was hurriedly shoveled into the break until it was filled and the leak was stopped. The concrete thus deposited formed the artificial stone, and it had remained in that condition for ten or twelve years at the time I saw it. The thought which this suggested was afterwards put to a practical use.

In October, 1874, a cyclone passed over Key West and made an opening one hundred and fifty feet in length through the sea wall at Fort Taylor. This wall was built in water from six to ten feet in depth, and was ten feet thick, being faced with granite of headers and stretchers in rises of two feet—stretchers about eight feet long, and headers running entirely through the wall. Above mean low water the rise of the tide is about one foot.

In building the wall, a coffer-dam had been used to protect the work from the force of the waves, but no attempt had been made to pump out the space within it. The concrete had, therefore, been dumped in place by means of a box with a movable bottom. The water had washed out a portion of the cement in the mixture of concrete, especially on the surface of each deposit, so that the backing of the wall was weak. Before it had given way there were cavities in it as large as a man's body, so that when struck by heavy seas the wall gave way and was broken into fragments.

Only a small sum of money was available for replacing the wall, and there were no derricks, winches or other plant. I remembered seeing, in an old storehouse at Key West, a large quantity of gunny bags that had been made in order to be filled with sand and piled up as a defence in time of war. These bags were made of very loose material,

like burlap, and were about three feet long and two feet wide. It occurred to me that the bags might be used as a means of placing the concrete backing of the wall mixed entirely dry. Probably placing wet concrete in bags or sacks was not then a novelty; certainly it is not so now, but I had never seen it used in bags either wet or dry, and, so far as I am aware, the method employed to rebuild the wall without a coffer-dam was entirely novel.

I arranged over the wall a platform built upon long trestles, and, after extemporizing small hoisting machines, began the work. After clearing away the débris, some of the stones were loaded upon the platform through which they were lowered into place. The first stone, a long stretcher, was laid upon the bottom, a formation of coral, which had previously been cut in steps with level tops to receive the stones upon an even bed. To lay the stones in mortar was a problem. I purchased some narrow and very thin muslin, and had the masons spread one piece of muslin with mortar about half an inch thick, and laid another piece of muslin over the mortar, precisely as one would make a mustard plaster for the sick chamber. The men that were employed as laborers were all amphibious, I am certain, for without protection save one or two flannel garments, they would go down to the bottom and stay until the average man would have been drowned; then they would come up for a minute or two, blow a little and go down again.

When the stone had been lowered nearly to the bottom, two men drew the sheets containing the mortar bed under the stone, which was then put in place and rammed down thoroughly with long-handled rammers, the bottom being directed by one of the divers, in undress, and the top being worked by men on the platform. The locating and leveling of the stones are matters of detail which need not now be described. When a header was laid, the mortar between sheets was wrapped entirely around the bed and build. When an entire course had been built in this way, the backing of concrete was put in. It was made of Rosendale cement and coral sand in the usual proportions. Stone chips from the granite, and fragments of bricks, were used to complete the concrete mixture.

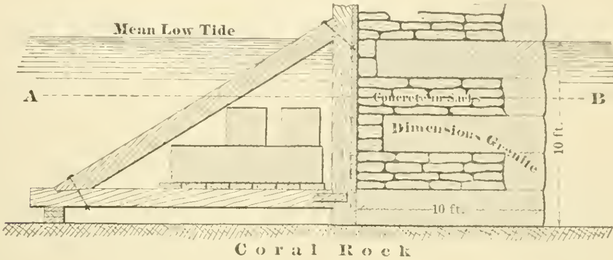
I had the wall backed by an arrangement of solid timber in right-angled triangles with one long side horizontal; and then placed planks on these long sides and loaded them with heavy stones. The triangles, thus loaded, formed a rigid backing for planks which in turn held the concrete in the wall and permitted it to be very thoroughly rammed without displacement. The temperature of the water was about 84°. The dry bags were handed to the men below water, who put them in place, carefully and rapidly, and they were thoroughly rammed in single layers of a thickness of about six inches. The timber in the temporary

supports for the backing was taken from the frames of old buildings which had been demolished.

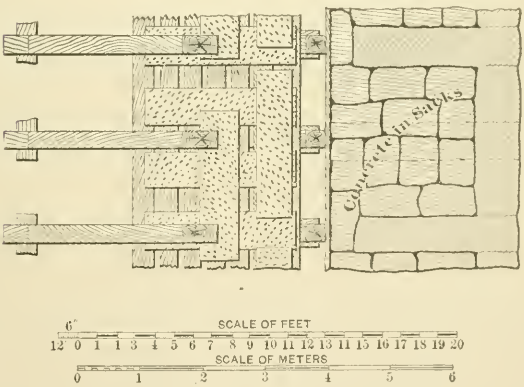
The bags were filled to about three-fourths of their capacity and were sewed up. Several hundred of them were made at a time, and they could be kept on hand until used, because, no moisture being used, the mixture did not set.

It was an amusing sight to see hands sticking up out of the water

Cross-Section.



Horizontal Section on Line A–B.



all along the line, passing down concrete bags and returning without the appearance of a head save at what seemed long intervals, when a man would come up and blow for a few minutes before returning to his work under water. In that way the concrete was placed until it was fully up to the level of the course of masonry, when the same process was repeated by putting on another course of stone and backing it with concrete. When the wall had reached the low water level the concrete was placed in the ordinary manner. I found, in looking over a little record that I happened to find this morning, that the concrete thus put in, estimating the bags at twenty cents each (which is a liberal price, as they would not have been put to any other use), cost $7.08 per cubic yard,

which is not a bad showing, considering the way in which the work was done.

I have a letter from the overseer at Fort Taylor, written just ten years ago, in which he says: "The dry concrete in bags, used in repairing the sea wall at this place, has proven to be a grand success. "That portion of it now to be seen is far harder than the rock of the "island. I found it to be so good, that upon being called upon by the "surgeon of the Marine Hospital at this place a few years ago to give "my opinion of the cheapest and best plan to secure a good foundation "to a sea wall which he had received orders to build around the hospital, "I recommended the use of dry concrete in bags. He adopted my recommendation, and the entire foundation was put down in that way, "and up to the present time not one particle of it has shown any signs "of giving out. Quite a number of the foundations to the piers of our "new bridge were also put down in that way, all of which up to the "present time stand well."

This was ten years after the completion of the work. I will say that any amount of prodding with a hard wood pole would be insufficient to detect the difference in hardness between the concrete and the granite.

Five years after the date of that letter, I had a special occasion to use the record of the work, and I wrote to the overseer asking him to make a careful examination and tell me its condition. It had then been in its position fifteen years. He wrote, "The wall is firm as the everlasting hills, although the earth and other materials behind it have "long ago been washed away, leaving the wall entirely unsupported, to "bear the force of the sea."

This wall projected about six feet above the water, and was ten feet thick, so that it really made a breakwater ten feet thick and about sixteen feet high. It is perhaps not very remarkable that it should stand the seas, although the force of the water is very great. What is remarkable, is that the concrete has not shown the slightest evidence of weakness or deterioration from being wet by the salt water, nor from its long exposure in that way. When concrete is put in under water, with the mortar wet in mixing, the cement washes away rapidly, and the strength of the concrete is materially diminished, but when it is dry inside, the pressure of the water is inward and keeps the cement in the mass instead of washing it away. The bags also prevented washing of the surface and with them the concrete could be made compact by ramming. About six hundred cubic yards were placed in that way. When the wall was completed, the parts of the muslin which projected from the joints on the face were removed by merely cutting them away with a knife. The stones were rammed into place as firmly as could have been done had they been in the open air, and the joints could hardly have exceeded one-fourth of an inch in thickness as a maximum.

DISCUSSION.

Mr. H. C. Thompson.—Does not the ramming process burst the bags?

Colonel Smith.—As I did not dive under the water I am unable to answer that question with certainty. I experimented with the bags above water and showed the men how to put them down by practical illustration. Not being entirely filled, the bags were very pliable, and the concrete could be rammed in position without bursting them. That could not have been done if the bags were filled. I have no question that there was force enough used to make the mass absolutely solid.

Mr. W. H. Searles.—I would like to inquire what wages were given to these amphibious creatures.

Colonel Smith.—The wages of ordinary laborers. Without desiring to advertise any kind or brand of cement, I would say that the cement used was the "Rosendale Cement," made by F. O. Norton & Company. This was mixed with the coral sand from the shore.

The President.—I believe that about the same time it was attempted on the docks here to do something with the cement in a dry state. Did they take advantage of your experience?

Colonel Smith.—I suppose not, because the description has never been published. They may have done the same thing, however. If they did, it was original with them, as it was with me. The only thing that occurred to me as being novel, was the putting in of concrete in bags for a submerged foundation, or wall, without previous wetting. It was absolutely dry.

Mr. H. C. Thompson.—I have used dry concrete on a limited scale and with good success. I had occasion to put in a foundation for a pier about five feet square and six feet deep, the place being filled with water. I mixed the concrete perfectly dry, and set my cap-stone on the concrete. I had occasion, about a month afterwards, to dig around the bottom, and found this concrete pier very hard indeed; quite as hard as any other I had put in.

Mr. C. G. Force.—I had some experience in the use of dry concrete about five years ago in the construction of the Rocky River Viaduct. There the river piers have concrete foundations resting upon rock in water twelve feet deep. The concrete was mixed on shore, and put into the water practically but not absolutely dry. It was mixed in this way: on a platform on the ground we first spread the sand, and then on top of that the cement; they were then mixed by being turned over and over with shovels, then the broken stone was spread on top of that, perhaps five or six inches thick, and then a slight sprinkling of

water. My instructions were to use only water sufficient to wet the surfaces of the stones, and the workmen took a pail of water in one hand and with the other hand spread the water; the mass was again turned over by the men with shovels, and then put into a box with a hinged bottom which was swung with a derrick and lowered into the water inside of a timber caisson without a bottom. The concrete was deposited uniformly over the foundation, but no attempt was made to pack it. A day's work for a gang of men was one layer about eighteen inches in thickness. By the next morning the concrete had hardened sufficiently to resist considerable pressure from an ordinary hand pole.

After the concrete had stood over night, undisturbed, the depressions of the surface were found to be filled with a very light whitish substance called, by the French, "laitance," which was removed by the use of ordinary hand pumps. The contractor complained that the cement was being pumped into the river and wasted, but the pumping was continued until all the surface had been gone over. The presence of "laitance" could easily be detected by using a pole with the lower end slightly broomed. Then followed another layer of concrete, and the next morning pumping was resumed. After the caisson had been filled in this way to the required height, the concrete was allowed two weeks to harden before the stone masonry was laid thereon.

The cement used was ordinary Louisville hydraulic cement, except that it was ordered quick-setting. The proportions were, one part sand, two parts cement, and four parts broken stone. Care was taken to have a tolerably free circulation of water through holes in the top of the caisson. This is necessary in order to have the cement set well, and also to maintain the same water-level inside and outside the caisson.

The concrete seemed to harden all right, and it has stood well. I have examined it frequently since the viaduct was completed and it has been examined by others and found to stand well. The masonry settled slightly and uniformly in proportion to the load, and it has not settled since the superstructure was completed. That portion of the caisson below water was left intact, and heavy riprap was deposited around the piers. A recent and careful examination failed to show the slightest crack in the masonry.

COLONEL SMITH.—The method I speak of permits of packing the concrete by ramming. Where it is put in in the ordinary way under water, ramming would do no good.

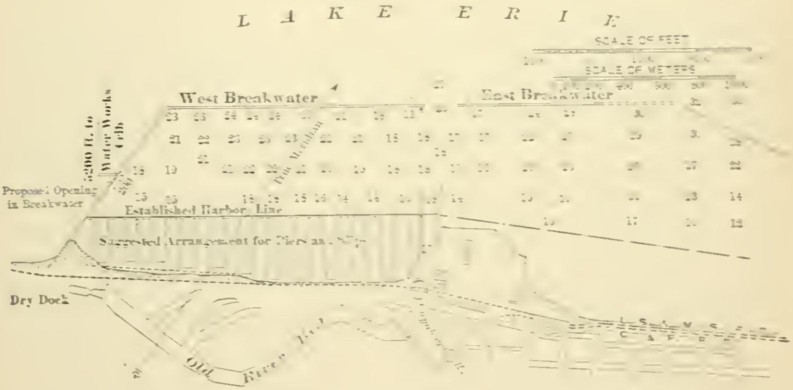
PRESIDENT RICHARDSON.—I had occasion to use dry cement once in the fall of 1874, in building chimneys where they stood in the water; I used the cement dry and put in the concrete, and it formed a large cake and hardened. I built the chimneys upon it, and they are standing all right yet.

IMPROVEMENT OF CUYAHOGA RIVER.

By Lieutenant-Colonel Jared A. Smith, Member of the Civil Engineers' Club of Cleveland.

[Read October 9, 1894.]

There has been more or less discussion with regard to the sanitary or unsanitary condition of the harbor, and the Chamber of Commerce has recently passed a resolution asking to have an opening made in the shore arm on the west side. The matter was referred to me, and I have submitted a report, of which I will give you the substance.



When there is a strong current in the river, owing to continued heavy rains or melting snows, the water carries much mud in addition to its load of sewage; and at such times the current which spreads to westward, after passing beyond the channel piers, is stopped by the west arm of the breakwater and turned westward, where it moves slowly around in the anchorage, which thus forms a settling basin.

During the summer, when there is but little current, the same principle obtains, although the settlement is then almost entirely from the vast quantity of sewage which is discharged into the river. There are, however, all sorts of débris and refuse in the river. The worst thing we have found, thus far, was the body of a man, which was dredged from the bottom about a year ago. This had probably drifted down the river with other unwholesome matter.

At nearly all times there are currents, more or less marked, along the shore of the lake from west to east, or from east to west, according to the direction of the wind.

The spurs on the breakwater at each side of the entrance were constructed for the purpose of checking and dispersing the currents, which at times are very strong and which then cause vessels to drift sideways and sometimes to strike the breakwater.

When the winds are from easterly directions, the discharge from the river into the lake is through the opening between the breakwaters, and the currents then carry the foul water directly past the waterworks crib which lies near the line between the harbor entrance and the projecting point of the shore to westward.

Were there a sufficient opening in the shore arm of the west breakwater, the current from east to west would pass through the harbor, and the discharge into the lake would be so far inside the water crib that danger of contamination would be greatly reduced.

When the winds are from northwesterly directions, as they are during a much greater part of the time than from northeasterly directions, the opening suggested would permit part of the shore current to pass through the harbor parallel to the shore. A large part of the filth would thus be carried out of the harbor either to eastward or westward and would settle in the lake where its effect would be inappreciable.

As a measure of city sanitation, I regard an opening in the west arm of the breakwater as of great importance. It is probable that the currents passing through the harbor would ordinarily be small, save perhaps in certain extreme cases in the opening itself; and they would therefore not be likely to remove any accumulations previously deposited; nor would they prevent the formation of a bar at the mouth of the river; but the deposition of sewage in the harbor would be greatly decreased in amount, and as a result the water in the anchorage would be less unwholesome.

DISCUSSION.

Colonel Smith then laid before the Club some suggestions for improving the commercial facilities of the harbor by the construction of wharves and slips along the shore on the west side of the piers extending to the harbor line inside the breakwater. He believed that this plan, which would afford more than five miles of wharf frontage, could be arranged so that this frontage should be accessible to all the railroads entering the city, and it would afford great facilities for the storage or transfer of coal and iron.

Access to steamers or other lake craft would be easier and cheaper than in the river, and an ample depth would be secured and maintained by the United States at comparatively little expense.

In the river, dredges will always be required to maintain the channel and they are not only expensive but greatly in the way, and the deeper the channel to be maintained the more must be the annual expense of dredging.

Colonel Smith referred to the method of maintaining channel in Maumee Bay, approaching Toledo Harbor. The cuts are made on the side of the channel where the deposit is deepest: the wheels of passing steamers stir up the middle and keep it clear, and the mud settles mainly along the sides.

It therefore costs less to remove the material from the side where the cuts are deeper, and the dredge is less in the way of passing vessels.

Mr. C. G. Force.—Will this plan of an opening in the west side increase the difficulties of vessels coming into Cleveland Harbor?

Colonel Smith.—It will decrease them. To a vessel coming in at the rate of five miles an hour, the current inside the harbor would not be perceptible.

Mr. W. H. Searles.—It has been stated that a certain captain, wishing to come to Cleveland, held his boat on the other side of the lake for a day or two, not wishing to run the risk of the current for fear he could not make the entrance to the harbor.

Colonel Smith.—I think that statement was made by Mr. Goulder at the Chamber of Commerce. Evidently the captain greatly overestimated the strength of the side currents at the entrance, and was unnecessarily timid.

THE CONTRIBUTION BOX.

Members of the associated societies, and other persons, are invited to send to the Secretary, for this department of the JOURNAL, such matters of general interest as may come to their notice.

Government Adoption of the Metric System.

At the World's Congress of Electricians at Chicago in 1893, the adoption of standard units of electrical measurement based on the centimeter, gram and second was recommended. The American Institute of Electrical Engineers petitioned the U. S. Congress in the spring of 1894 to adopt those units as the legal standards in the United States, and Congress accordingly passed an Act last summer establishing them. Some details were left to be attended to by the National Academy of Sciences. Among the interesting points in the debate upon the bill in the House of Representatives on the 9th of June were the reference to the constitutional authority of Congress to fix the standard ef weights and measures, the statement that Germany and Great Britain had already adopted the electrical standards in pursuance of the recommendation of the Congress at Chicago, and the argument that the expenditures of the United States Government for electricity are now so large that it is a matter of commercial importance to establish legal units of measurement for it. Hon. Charles W. Stone, of Pennsylvania, a member of the Committee on Coinage, Weights and Measures, had charge of the bill.

In the London *Times* of November 21, 1894, is the report of a general meeting of the New Decimal Association held on the preceding day at the London Chamber of Commerce, where, after the passage of a resolution about a Select Committee of Parliament, it was voted, "That the Hon. William L. Wilson be informed of the present position of the movement in this country for adopting the metric weights and measures, and that he be urgently invited to use his influence to secure such legislation as may provide for the adoption of this system of weights and measures in the United States." The Chairman, Sir Samuel Montagu, M.P., stated that he had received promises of active co-operation from Mr. Wilson, the author of the recent Tariff Bill in the United States.

The Myrtle Avenue Improvement of the Brooklyn Elevated Railroad.

Apropos of Mr. A. A. Stuart's description of the Brooklyn Elevated Railroad, which appears in this number of the JOURNAL, we note that at the meeting of the American Society of Civil Engineers held September 5th, Mr. O. F. Nichols presented an account of the Myrtle avenue improvement on that railway, describing an attempt at improvement in grades and in stations, and noting the difficulties met, the methods of overcoming them and the resulting gain.

The grades were reduced by cutting out sections from near the tops of the columns at the summit, and the stations (two in number), were moved bodily on heavy flat cars. The entire cost of the improvement was about $40,000, and the annual saving effected is estimated at about $6,050.

THE LIBRARY.

It is proposed to notice briefly in this department of the JOURNAL such engineering publications as may find their way to our shelves.

Publishers are requested, in sending works for review, to state the prices of same.

New Roads and Road Laws in the United States. By Roy Stone, Vice-President of the National League for Good Roads, and U. S. Special Agent and Engineer for Road Inquiry, Department of Agriculture. New York: D. Van Nostrand Co., 1894. 166 pages, $4\frac{1}{2}$ x $7\frac{1}{2}$ inches.

In the progress of humanity from individualism and savagery toward socialism and civilization, a very early step must have been that of the construction of roads, for their necessity must have been early felt, and the inability of the individual to grapple with the problem is here peculiarly manifest.

That the matter of road construction and improvement is in the air, is evidenced by the large number of works upon the subject, now appearing; and the present volume, prepared, as it is, by the Vice-President of the National League for Good Roads, who, at the same time, fills the office of U. S. Special Agent and Engineer for Road Inquiry, is a valuable contribution to this literature. The information here presented was compiled principally in order to reply to inquiries as to the new legislation for road improvement and the working of that legislation, the cost and methods of road construction, and the effects of road improvement where it has been accomplished.

While our consular reports have kept us informed as to road making in foreign countries, our author tells us in his preface that the densest ignorance still prevails in respect to our home efforts and their results.

The author attempts only to give a condensed account of recent progress in American road making, with details of the examples which have been most conspicuously successful, together with some suggestions for road legislation and for road construction.

After reviewing the recent history of road improvement and the present status of the government road inquiry, the author proceeds to a discussion of the practice in several states where road improvement has been seriously undertaken. He then discusses the local option road law in New Jersey and amendments proposed. State Aid, including the furnishing of convict labor, is next discussed, and the author then shows, by citing the inducements held out by railroad companies, the favorable attitude of such organizations toward the movement.

Different forms of road construction are then discussed, and the work concludes with an appendix containing abstracts of new and proposed road laws, reports of road commissions, etc.

Hoisting Machinery, THE MECHANICS OF —, including Accumulators, Excavators, and Pile-Drivers. A Text-Book for Technical Schools and a Guide for Practical Engineers. By DR. JULIUS WEISBACH and PROF. GUSTAV HERRMANN. Authorized Translation from the Second German Edition, by Karl P. Dahlstrom, M.E., late instructor of mechanical engineering at Lehigh

University. With 177 illustrations. London: Macmillan & Co., and New York, 1893. 329 pages, $5\frac{1}{2}$ x 9 inches, and index. $3.75.

The author here presents an excellent translation of a portion of Weisbach's great work on Engineering Mechanics, not yet laid open to English readers.

As in other portions of that work, the treatment is remarkably excellent, and, with the aid of the admirable illustrations reproduced from the German edition, the matter is put before the reader in easily comprehensible form, so that little or none of his energy is devoted to wrestling with the author's or translator's obscurities, and practically all of it is thus left free to deal with those of the subject itself.

As in those portions of Engineering Mechanics which have thus far appeared, numerous examples are given and are worked out in detail, and in these the author's metric dimensions and weights have been translated into English measure, the figures for the latter being given in brackets.

The treatise naturally begins with the lever, as being perhaps the simplest form of hoisting machine, and after treating of its developments, the lever-jack, gearing, rack-and-pinion jacks, and screw-jacks, it passes to the consideration of pulleys, simple, compound and differential, windlasses and winches. In treating of this portion of the subject the cantilever hoisting and conveying machines used upon the Suez Canal are described and illustrated, but the more recent American development of the same system is not described.

Hydraulic and pneumatic hoists and elevators are satisfactorily described and illustrated in Chapter IV, and hoisting machinery for mines in Chapter V, concluding with a brief reference to the steam hoisting engine. Chapter VI is devoted to the subject of cranes and sheers, including the modern traveling crane. This latter device receives less exhaustive treatment than its very extensive use in modern engineering works would seem to demand, and the matter of the employment of electricity for its operation is barely referred to. Chapter VII treats of excavators and dredges, illustrating and describing the commoner forms of scoop, grapple and bucket dredges, but omitting reference to the hydraulic dredge. Chapter VIII treats of pile-drivers, including the direct-acting steam pile-driver and Shaw's gunpowder driver.

Sewage Disposal, Modern Methods of —, for Towns, Public Institutions and Isolated Houses. By George E. Waring, Jr., M. Inst. C. E. New York: D. Van Nostrand Co. London: Sampson Low, Marston & Co., Limited, 1894. 243 pages, 5 x $7\frac{1}{2}$ inches, and index.

It has been said that the preface of a book is always the part last written and last read. The distinguished author of this work has evidently determined that his introductory remarks shall not be lost sight of, whether or not this saying be true, for he states the purpose of his work not only in his brief preface, but in his concluding chapter, where he states that this purpose is to set forth in a simple way and in terms as free as possible from technical nomenclature, the practice and the principles of sewage disposal. This object he has accomplished in a very acceptable manner. After a brief general consideration of the subject, he proceeds to a discussion of what sewage is, and we are here told that it is practically water, containing, on an average, one part in one thousand of mineral impurities, and another part in one thousand of organic matter, and that the object sought in sewage purification is to render the one part of organic matter harmless, and to remove it, leaving the 999 parts of water pure.

Absolute purity, or such purity as would render the water fit for drinking pur-

poses, is here not necessarily intended, but only such as will render it permissible to discharge the effluent into streams which may again be used for a supply of drinking water.

The layman instinctively regards the utilization of sewage for the fertilization of farms as the natural and rational means of disposal, and its discharge into streams as a mere make-shift which our ignorance of the former method compels us to adopt. Our author, however, points out, first, that sewage farming can rarely be made to pay in an agricultural sense, and furthermore that the discharge of sewage into streams may yield, in the development of fish life, as large a return as its distribution over a farm.

The four methods of disposal treated of, are: irrigation, filtration, chemical precipitation and sedimentation, each of which is treated in detail.

As in every other modern work on this subject, the labors of the Massachusetts State Board of Health come in for extensive and favorable notice and study.

In the chapter on sewage farming, the experiments at Bedford, at the Craigentinny Meadows, Edinburgh, and at Aldershot are briefly reviewed, and the report of the British Sewage Commissioners of their examination of the irrigation fields of Milan is quoted, to the effect that they find "no evidence whatever of the slightest injurious tendency of irrigation conducted with the waters of the Vettabbia (sewage irrigation), beyond those of other districts around, and where plain water is employed."

Sewage Disposal in the United States. By GEORGE W. RAFTER, M. Am. Soc. C. E., and M. N. BAKER, Ph.B., Associate Editor *Engineering News*. Second Edition. New York: D. Van Nostrand Co. London: Sampson Low, Marston & Co., Limited, 1894. 589 pages, 6½ x 10 inches.

This work forms an admirable complement to the one just noticed. Col. Waring's book discusses briefly the general principles of the subject of sewage disposal, and, while the first and larger part of the present work is ostensibly devoted to the same task, it is marked by a very much greater and more exhaustive use of examples taken from actual practice. The former may be said, therefore, to tell us how to do it and how not to do it, while the latter tells us, at much greater length, how it is done and not done.

Our authors hold that, owing to the dissimilarity between American and European conditions, and owing to the rapid development of so much work in this country, with the resulting accumulation of experience here, it is at least far less necessary now for Americans to visit Europe in search of ideas on this subject than was formerly the case.

Here, as in Col. Waring's book, the reports of the Massachusetts State Board of Health are quoted at considerable length.

The second part of the work, consisting of 217 pages, contains an admirable illustrated description of many of the most important American sewage-disposal works, including the chemical precipitation plants at Coney Island, Round Lake, White Plains, and Sheepshead Bay, N. Y.; at East Orange and Long Branch, N. J., and in the Mystic Valley at Worcester, Mass.; the proposed installation at Providence, R. I., with discharge into tide water and chemical precipitation; broad irrigation at Worcester and Concord, Mass.; at Pullman, Ill., and at the Rhode Island State Institutions; intermittent filtration at South Framingham and Medfield, Mass.; London, Ont.; Rochester, Minn.; Marlborough, Mass.; Gardner, Mass., and Summit, N. J., and many instances of sewage irrigation in the West.

United States Geological Survey. THIRTEENTH ANNUAL REPORT OF THE —, 1891–92. By J. W. Powell, Director. Washington: Government Printing Office, 1892, and other documents.

The Annual Report occupies three large volumes, the first containing the report of the director, with administrative reports of chiefs of divisions and of the heads of independent parties. The second contains an account of a second expedition to Mt. St. Elias, by Israel Cook Russell, and papers on the Geological History of Harbors, by Prof. N. S. Shaler; on the Mechanics of Appalachian Structure by Bailey Willis; on the Average Elevation of the United States, by Henry Gannett; on the Rensselaer Grit Plateau in New York, by T. Nelson Dale; and on the American Tertiary Aphidae, by Samuel Hubbard Scudder.

The third part is devoted to the subject of irrigation, and is made up of three papers and two reports. The papers are those of Mr. F. H. Newell, on Water Supply for Irrigation, and of Mr. Herbert M. Wilson on American Irrigation Engineering and on Engineering Results of Irrigation Survey. The reports, by Mr. A. H. Thompson, treat respectively of the Construction of Topographic Maps and the Survey of Reservoir Sites in the Hydrographic Basin of the Arkansas River, Colorado, and of the location and Survey of Reservoir Sites during the fiscal year ending June 30, 1892.

Two maps of the United States, enclosed with the first volume, show respectively the progress of topographic survey during the fiscal year 1891 and 1892, and that of geologic mapping.

Prof. Shaler's paper on the Geologic History of Harbors, in the second volume, is a most elaborate treatise of 111 pages, profusely illustrated with plans and photographic views of harbors in different parts of the country. Mr. Willis' paper is a no less exhaustive discussion of the mechanics of a mountain range, and is illustrated not only with a large number of maps and sections, but also with photographic views of distortions artificially produced in layers of beeswax, hardened with plaster of Paris or softened with Venice turpentine, as occasion required. The artificial formations composed of these strata were placed in a machine made for the purpose, and the horizontal pressure required was applied by means of a plunger operated by a screw, the layers in the meantime being loaded with small shot which were placed in the box containing them, and exerted a pressure of five pounds per square inch.

OF a large number of other and valuable publications received from the Geological Survey, we can but briefly notice several which are of special interest to the engineer as well as to the geologist.

A MANUAL OF TOPOGRAPHIC METHODS. By Henry Gannett, Chief Topographer. Monographs, Vol. XXII, 1893. Price, $1.00.

A very valuable exposition of the topographic methods at present in use by the Survey, with illustrated descriptions of the principal instruments used and methods employed. The five principal instruments are the theodolite, the plane table with telescopic alidade, the plane table with ruler alidade, the odometer and the aneroid. Chapter V, upon sketching and the use of topographic forms, is beautifully illustrated by portions of the map of the United States now being prepared by the Survey. An appendix of 168 pages contains a valuable series of tables for the use of the topographer, including barometric, altitude and projection tables, a table of logarithms, etc. A colored map of the United States shows the progress made in triangulation, topography and astronomic location.

Mineral Resources of the United States, for the calendar year 1893. By David T. Day, Chief of Division of Mining Statistics and Technology. 1894. Price, 50 cents.

This is the tenth annual volume of this series, and its 794 pages form an invaluable account of the mineral resources of the country at the present time.

Geographic Dictionaries of Rhode Island, Massachusetts and Connecticut. Bulletins Nos. 115, 116 and 117.

These dictionaries are designed to accompany the atlas sheets of their respective States, published by the U. S. Geological Survey in co-operation with the State Government. They contain all the names given upon those sheets, and no others. Under each name is a brief statement of the character and locality of the town or other feature, and opposite is the name of the atlas sheet or sheets upon which it is to be found. The maps are published upon a scale of 1 : 62,500, or very nearly one mile to the inch, with contours spaced 20 feet vertically.

Bibliography and Index of the Publications of the United States Geological Survey, with the laws governing their printing and distribution. By Philip Creveling Warman. 1893.

It is needless to say that this is a work of the greatest value to those having occasion to refer frequently to the publications of the Survey. The Bibliography is practically a table of contents of the several publications, including the annual reports Nos. 1–12, monographs Nos. 1–20, bulletins Nos. 1–99 (except Nos. 87, 88 and 89), Mineral Resources, Vols. I–VIII, such portions of the geological atlas, with auxiliary and subsidiary maps, as have been completed, and a few miscellaneous brochures. The index, alphabetically arranged, covers 169 pages.

A New Declinometer for Orientation, and a New Variometer. Preliminary Reports Upon ——.* By Adolph Fennel. With one lithograph plate. Reprint from Mittheilungen aus der Markscheidekunst, published by the Society of Mine-Surveyors of Rhenish Westphalia. Freiberg in Sachsen. Craz & Gerlach (Joh. Stettner), 1894. Pamphlet, 12 pages.

The declinometer here described is designed for determining with accuracy the position of the meridian in mines, etc. When in use it is attached to the theodolite or transit in such a manner as to stand in front of the object-glass of the latter.

The object end of the transit telescope is furnished with an attachment containing a half-lens, an inclined mirror and a glass scale. A ray of light, falling upon the mirror, is reflected forward through the scale into the body of the declinometer, in which the magnet, consisting of a small and light steel tube, is suspended horizontally by a long thread made from melted crystal. The magnet contains a small mirror placed transversely to its axis, and the ray of light is reflected back from this mirror through the half-lens into the object-glass of the telescope on the transit.

The variometer, as its name denotes, is used to determine *variations* in the declination. In its general arrangement it is similar to the declinometer, but it is used without the transit, a small telescope being attached for the purpose of observing the motions of the swinging magnet, which contains a prism instead of the mirror used in the declinometer.

* Vorläufige Mittheilungen über ein neues Declinatorium für Orientirungsmessungen und über ein neues Variometer.

Inhalt der mechanisch-technischen Zeitschriften (Contents of the mechanical-technical journals). Supplement to the *Zeitschrift des Vereines deutscher Ingenieure.* Berlin. Vol. IV. 1893.

This Index to current technical literature is in some respects similar to that published in our own JOURNAL. It is issued as a supplement to the Journal of the Society of German Engineers, and embraces a large number of technical papers, both German and foreign. It is published quarterly, but there seems to be no attempt to re-issue annually under one alphabetical arrangement, as is done in the case of our Index, a feature which of course adds very greatly to the value of the latter.

THE JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES appears in the list of journals indexed, but the references to that journal appear to be very few.

Annual Report of the Surveying Department for the year 1893. Boston, 1894.

Mr. Pierre Humbert, Jr., City Surveyor, condenses his report proper within eleven pages, and then hastens on to devote thirty to the more interesting study of the growth of the city, with special reference to its requirements in the future.

To illustrate this portion of the report he appends three most interesting maps. The first is a map of Boston, bearing the date 1630; the second is a plan of the harbor showing the location of the forts in 1775, and the third is a map of the city and vicinity, showing the districts which have been "made" and those which may still be reclaimed.

Society Proceedings.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA. Proceedings of ——. September, 1894. Vol. X, No. 7.

This number contains the account of the meeting of September 20th, at which Mr. Selwyn M. Taylor presented a paper upon the waste of coal in mining, based chiefly upon his experience in the Pittsburg coal bed, but applicable, none the less, with but very slight variations, to all the bituminous measures in the United States from the Allegheny to the Rocky Mountains.

October, 1894. Vol. X, No. 8.

This number, of thirteen pages, contains papers on "Lake Shipments, and Handling of Lake Coal," by Mr. G. E. Tener; on "Weathering of Fuel," by Mr. William White; and a discussion on the comparative value of coal, oil and gas, based upon experiments made by the National Transit Company.

Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XIII. DECEMBER, 1894. No. 12.

TRANSITION CURVES.

BY EDWIN E. WOODMAN, MEMBER OF CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

[Read October 1, 1894.]

FOR transition curves, to connect circular curves with their tangents in railways, those derived from equations in the form of

$$y = ax^n \qquad (1),$$

possess the simplicity and facility of application favorable if not necessary to the general introduction of these curves in practice.

So long as n is greater than 1, the curves which represent this equation are convex towards the axis of X, as in Figure 1.

FIG. 1.

By giving particular values to the letters, a, n and x, we control the radius of curvature of the several derived curves and thus adapt them to the object in view. They will all start from O, the origin, with an infinite radius at right angles to OX, that is, will be tangent to OX at O; and, proceeding from O, the radius will diminish from point to point along the curve, under the law of the equation, according to the numerical values assumed for the several letters. What we have to do, then, in a given case, is to give such values to a and n that in a reason-

able distance, x, we may come to a point P in the curve where the radius of curvature of the transition curve is the same as the radius of the circular curve to which the transition curve is to be applied. By a reasonable distance x is meant, such a distance that the putting in of transition curves will not lengthen the original curve by more than 200 feet at each end.

On experimenting with the equation it will be found practicable to devise, for any particular curve, say a 2 degree curve, a number of transition curves of varying length. But the desirability of this is doubted. It appears preferable to design but few transition curves, and then to make each one applicable to several circular curves by cutting it at the proper radial points. What follows contains the elements of three of these curves; the first adapted to circular curves up to 1 degree, the second up to 3 degrees, and the third up to 10 degrees; keeping in mind what has already been said about not lengthening the original curve unreasonably by means of the transition, and also the fact that most of the main track curves in use are under 4 degrees, so that the best in a choice of transition curves may well be applied to these lighter curves.

In forming these curves there has been assumed in each case such a value for a that, when x equals 100 feet, y shall equal 0.22 of a foot, this value of y being the departure of a 15 minute curve from its tangent at the distance of 100 feet from the beginning of the curve; and for n the values $2\frac{1}{2}$, 3 and 4; so that the equations become,

$$y = ax^{\frac{5}{2}} \qquad (2),$$
$$y = ax^{3} \qquad (3),$$
$$\text{and} \quad y = ax^{4} \qquad (4).$$

The choice made of the value of a is based partly on the intention of adapting the transition curves to circular curves commonly used, such as 2°, $2\frac{1}{4}$°, $2\frac{1}{2}$°, etc., instead of fitting circular curves of unusual radii to transition curves ending in the same radii; and, for the rest, on the consideration that the fifteen minute curve may well be taken as the inferior limit, below which the use of transitions would not apply. Some engineers would perhaps begin with the 1-degree curve.

Using these equations, and varying the value given to a, we may form transition curves, flat or sharp, at pleasure. With the same a, they increase in sharpness in the order of the powers of x.

For given values of a and x, ordinates y are deduced from the equation, and these enable one to lay out the curve from OX by offsets.

Next, to find the radius of curvature at any point, we have from the calculus the general formula,

$$R = \frac{\left(1 + \left(\frac{dy}{dx}\right)^2\right)^{\frac{3}{2}}}{\frac{d^2y}{dx^2}}$$

In the case of

$$y = ax^{\frac{5}{2}} \qquad (2),$$

we have

$$\frac{dy}{dx} = \frac{5}{2} ax^{\frac{3}{2}};$$

$$\frac{d^2y}{dx^2} = \frac{15}{4} ax^{\frac{1}{2}};$$

and, taking $x = 100$ feet and $y = 0.22$ feet, as already assumed, the value of a deduced from (2), is

$$a = \frac{22}{10{,}000{,}000}.$$

On substituting these values in the above expression for R, it will be found that, for the practical purpose we have in view, the numerator reduces to 1, and the whole expression to

$$R = \frac{12121}{\sqrt{z}}, \qquad (5)$$

in which z is the number of 100 feet stations in x, resulting from the substitution of $100z$ for x, in the final algebraic operations.

Then, to find the distance on OX to the point in the curve where R has a particular value, as 5730, substitute this value for R in (5) and solve for z.

Next, as to the total angle consumed by the transition curve, it is true of all curves answering to equations of the form

$$y = ax^n,$$

that the subtangent, Tx in Figure 1,

FIG. 1.

equals $\frac{x}{n}$, thus:

$$y = ax^n$$

$$dy = nax^{n-1}\,dx$$

$$dy : y :: dx = \frac{dy}{nax^{n-1}} : Tx$$

$$Tx = \frac{y}{nax^{n-1}} = \frac{ax^n}{nax^{n-1}} = \frac{x}{n}.$$

Thus, for equation,

$$y = ax^{\frac{5}{2}}, \qquad Tx = \frac{2x}{5};$$

for

$$y = ax^3, \qquad \text{"} = \frac{x}{3};$$

and for

$$y = ax^4, \qquad \text{"} = \frac{x}{4}.$$

Having y and Tx, we obtain the angle at T:

$$\text{Tang. } T = \frac{y}{Tx}.$$

Similarly, from y and Ox, we obtain the angle O, and chord OP, enabling us to locate the point P from O with transit and tape. These conditions are general, so that for any point in the curve the corresponding subtangent, angles and long chord, may in like manner be determined.

Having now obtained the total angle, T, of the transition curve, up to the point where the radius of the transition curve equals the radius of the given circular curve, it remains to take from the end of the circular curve the length due to the same angle, and then put the transition curve in the place of it. The result will be to give a parallel tangent lying outside of the original tangent, as shown in Figure 2.

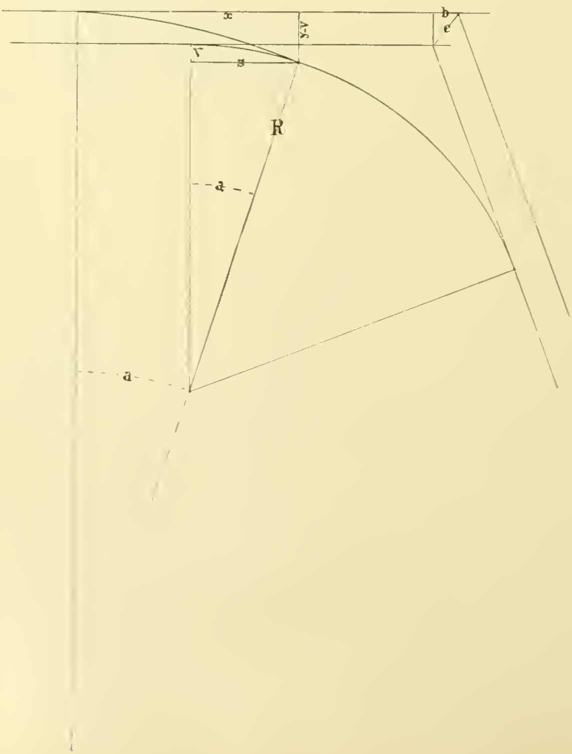


Fig. 2.

The distance between these tangents obviously is y for the whole transition, minus the versine of the transition angle into the radius of the circular curve; or $y - v$, Fig. 2.

Finally, we have to move the circular curve, with its attached transition curves, inwards, towards the center of the circular curve, the distance c, shown between the vertices in Fig. 2; or, we have, for the additional length of tangent, to accommodate the transition curve, $x + b - s$, Fig. 2. The values of b and c can of course be found when the vertex angle of the circular curve is known or is assumed.

It is not necessary to repeat the work for the other two equations, the operations being similar; but it may be noted, as to radius of curvature, that for

$$y = ax^3, \qquad R = \frac{7575}{z} \tag{6}$$

and for

$$y = ax^4, \qquad R = \frac{3787}{z^2} \tag{7}$$

z being in stations of 100 feet as before.

The radius of curvature may be approximated differently without resort to the calculus. If one minute of any circular arc be taken as unity, the radius of that circle will be 3,438 to the same scale. Hence if one minute of a circular arc is m, the value of radius is,

$$R = 3{,}438m \tag{8}$$

and, if one minute of arc of the transition curve at any point be supposed to coincide with the arc of a circle, we may obtain the radius of curvature of the transition curve at that place by substituting the length of that minute of arc for m in (8).

To find R in this way, first obtain the angle T for a number of values of x having a common difference, say 10 feet. The increase in the length of the curve, corresponding to one of these differences, will also, for practical purposes, be 10 feet. Let T, T_1, T_2, be three consecutive values of T in minutes. Then

$$\frac{10}{T_1 - T} = m$$

and

$$R = \frac{34380}{T_1 - T}.$$

This is the average radius of curvature for so much of the curve as lies between the tangent points of T and T_1. Deduce a corresponding value of R from T_1 and T_2, and then the average of these two values of R may be taken as the radius of curvature at the middle point, or tangent point of T_1.

On page 684 will be found, in tabular form, adapted to certain circular curves in common use, elements of these transition curves sufficient for laying them out. If other data are needed, or are desired in a particular case, the equations will supply them. Anyone interested in the subject will prefer to adapt formulæ to his own practice rather than see a cumbersome and vain attempt made to anticipate all cases here. Nor has it been deemed essential to the present object to assume that these transition curves would be laid out in any other ways than by offsets and by setting the instrument at the beginning of the curve. Other expedients would hardly ever be called for, but, if they should be demanded, the simplicity of the curves will make the calculations short and easy.

The approximations for R, given in (5), (6) and (7), are sufficiently close.

In the curve $y = ax^{\frac{5}{2}}$, the value of R at 100 feet from the origin, is by (5), 12,121 feet. The more exact value is 12,170 feet. Both lie between the radius of a 28-minute curve and that of a 29-minute curve. The effect of the differences thus due to using the foregoing approximate values for R, happens to fall on the right side; that is, the true radius of curvature is in every case a little longer than the one derived from (5), (6), or (7), consequently the circular curve is compounded with a transition curve a little flatter than itself, and not a little sharper. In the curve $y = ax^3$, extended to join a 3-degree curve, the actual radius at the point of compounding would be that of the 2° 58′ curve. The worst result from using these values of R would be the case of the 10-degree curve, the sharpest in our scheme. In that case the circular curve would be compounded with a transition curve having at the point of junction the radius of the 9° 41′ curve. This worst difference is wholly without practical import. It would be better practice to compound these two curves than to change the circular curve from 10° to 9° 41′, for the latter course would be making the greater yield to the less; and besides, the radius of curvature does not enter into or affect in any way the exactness of all the other elements of the transition curve, by means of which it is to be located.

The equation $y = ax^3$ is that of the cubic parabola. I am aware that the cubic parabola has been advocated as a transition curve, but I have not seen it worked out. And so of a number of other curves. Several authors, whose writings on this subject I have found it convenient to examine, advocate a transition curve in which the radius of curvature is inversely proportional to the length of the curve itself, or else to the square of that length. In the foregoing pages the radius of curvature is inversely as some power of the abscissa x. I see no practical difference in the two systems, except that the latter is simpler in its

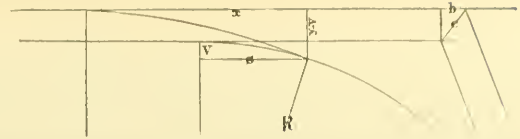
mathematical features than the former, and therefore seems more likely to command the attention of working engineers.

It is to be remembered that any transition curve should be flat in the first part of its length, the better to perform the service of gradually turning the cars up to their maximum and uniform change of direction on the circular curve. The difference in length, then, between this fla curve and its abscissa, is certain to be so small, that whether the radius of curvature be proportional to the length of the one or the other is a matter of no importance. The thing to be practically accomplished is, to effect the change in direction from tangent to circular curve gradually, so as to relieve to a sensible degreee the shock that is experienced without this arrangement; and for this object a formula easy of comprehension and application will be likely to make its way against one possibly higher in theoretical conception but of corresponding complexity.

An easy transition is the first desideratum, and, in first securing that, no attention need be paid to the change in the elevation of the rails of the curve, necessary to counteract the centrifugal force. Theoretically it is as easy to make this change for one radius as another, while it is well understood that, owing chiefly to the varying velocities under which the curve is traversed, but also in considerable degree to imperfections in track work, it is practically impossible to meet the theoretical requirements. If a transition curve were necessary to control the movements of an astronomical telescope, the highest refinements in theory, and the finest adjustments in practice, would be demanded; but the case is altogether different where 80-pound rails are being bent with ordinary track tools in the hands of section men, faithful and efficient as those servants usually are within their limitations.

For instance, if the claim is made that the radius of the transition curve should be inversely proportional to the length of the curve, then the change in the elevation of the rails on this form of transition curve, which according to theory should be inversely proportional to the same radius, would increase directly as the length of the transition curve, so that, if it were half an inch at 100 feet, it would be an inch at 200 feet. This theoretical condition would be well enough satisfied by the curve of $y = ax^3$, in which the radius of curvature is inversely as x; but not so well by the curve of $y = a\,x^{\frac{5}{2}}$, in which the radius of curvature is inversely as $\sqrt{x}$. Yet how serious would the latter case be in practice?

It may be taken for granted that in any case the section foreman will taper the elevation as uniformly as his eye will permit throughout the length of the transition curve, just as he now does on the tangent rails for an indefinite distance from the ends of a curve. The error from this cause, between the theoretical and the actual elevation in the curve



Equation	x	y	R		T	O	OP	s	v	x—s	y—v
$y = ax^{\frac{5}{2}}$	28	.01	15′	22918			28				
	50	.04					50				
	100	.22				07′	100				
	111.9	.29	30′	11460	22′	09′	111.9	73.3	.23	38.6	.06
	200	1.24				21′	200				
	251.5	2.21	45′	7640	1° 17	30′	251.5	171.1	1.92	80.1	.29
	300	3.43				39′	300				
	350	5.04				49′	350				
	400	7.04				1° 00′	400.1				
	447.5	9.32	1°	5730	2° 59′	1° 12′	447.6	298.2	7.77	149.3	1.55
$y = ax^3$	50	.03					50				
	100	.22				07′	100				
	132.2	.51	1°	5730	40′	13′	132.2	66.7	.39	65.5	.12
	165.2	.99	1° 15′	4584	1° 02′	21	165.2	84.0	.77	81.2	.22
	198.3	1.72	1° 30′	3820	1 29	30	198.3	97.8	1.25	100.5	.47
	231.4	2.72	1° 45′	3274	2 01	40	231.4	116.2	2.06	115.2	.66
	264.4	4.07	2°	2865	2 38	53	264.4	131.6	3.03	132.8	1.01
	297.4	5.79	2° 15′	2547	3 21	1° 07	297.5	148.8	4.35	148.6	1.41
	330.5	7.94	2° 30′	2292	4 08	1 22	330.6	165.2	5.96	165.3	1.98
	363.5	10.56	2° 45′	2084	5 00	1 40	363.7	181.6	7.93	181.9	2.63
	396.6	13.72	3°	1910	5 55	1 59	396.8	196.9	10.18	199.7	3.54
$y = ax^4$	50	.01					50				
	100	.22					100				
	115	.38	2°	2865	46′	11′	115	38.3	.26	76.7	.12
	121.9	.49	2° 15′	2547	55′	14	121.9	40.7	.33	81.2	.16
	128.5	.60	2° 30′	2292	1° 04′	16	128.5	42.7	.40	85.8	.20
	134.8	.73	2° 45′	2084	1 14	18	134.8	44.8	.48	90.0	.25
	140.8	.86	3°	1910	1 24	21	140.8	46.7	.57	94.1	.29
	152.1	1.18	3° 30′	1637	1 46	27	152.1	50.5	.78	101.6	.40
	162.6	1.54	4°	1433	2 10	32	162.6	54.2	1.02	108.4	.52
	172.4	1.94	4° 30′	1274	2 35	39	172.4	57.4	1.29	115.0	.65
	181.8	2.40	5°	1146	3 02	46	181.8	60.7	1.61	121.1	.79
	190.6	2.91	5° 30′	1042	3 29	52	190.6	63.3	1.93	127.3	.98
	199.1	3.46	6°	955	3 59	1° 00	199.1	66.4	2.31	132.7	1.15
	215.0	4.70	7°	819	5 00	1 15	215.1	71.4	3.12	143.6	1.58
	229.8	6.14	8°	717	6 06	1 32	229.9	76.2	4.06	153.6	2.08
	243.8	7.78	9°	637	7 16	1 50	243.9	80.6	5.12	163.2	2.66
	256.9	9.58	10°	574	8 29	2 08	257.1	84.6	6.28	172.3	3.30

of $y = ax^{\frac{5}{2}}$ would at the most be an eighth of an inch. In view of what we may reasonably expect of men employed in track repairs, it would be useless to apply theoretical niceties to an error so insignificant and beyond control as this. Thus, up to 3-degree curves, there would be no sensible difference between theory and practice. For the higher curves, the difference in elevation of the rails should be specially computed and applied.

First put in the transition curves, and then do what is possible in the way of regulating elevation and depression of rails. These matters should be in the care of an engineer. Alignment, grades, and the adjustment of curve elevations, should be regulated by him. Where this is not the rule, the ends of every curve and of every transition curve should be plainly marked for the section foreman, either by posts set at the side of the track, or by white paint on the rails. A precaution of this kind would prevent that deformation of the ends of curves which is found in all tracks that have been long in use, and which have not been supervised and corrected in these particulars by engineers.

DISCUSSION.

October 1, 1894.

Mr. Archibald Johnson (Member).—From a cursory examination of Mr. Woodman's paper, I am satisfied that he has the proper solution of the transition curve.

Ordinarily, railroad curves are not flattened at the ends, excepting as they are eased off by the track-layer. The only thing of the kind I have ever seen was on the Dakota Division of the Northern Pacific Railroad. Mr. D. C. Lindsay, the Assistant Chief Engineer, required the locating engineers to flatten all curves of more than $\frac{1}{2}°$. The maximum curvature on this division was 4° curves. In flattening, we commenced with a 30′ curve; at 50 feet we compounded to a 1° curve; at 100 feet we compounded to a 1° 30′; at 150 feet to a 2° curve: at 200 feet to a 2° 30′ curve; at 250 feet to a 3° curve; at 300 feet to a 3° 30′ curve; and at 350 feet to a 4° curve. If we did not have room we used some submultiple of 50 feet for our points of compound curvature, but we always carried out the principle. In order to get the semi-tangent and consequently the B. C. and E. C., it became necessary to compute a set of tables giving the length of the semi-tangent corresponding to each point of compound curvature for chords of 50, 40, 30, 20 and 10 feet. Knowing this, it was an easy matter to compute the portion of the semi-tangent corresponding to the body of the curve.

To simplify the running out of these compound curves, we computed the angles from the tangent to these points of compound curvature; so that in running them out, all we had to do was to set up the

transit at B. C. and deflect and measure until we got to the body of the curve, which was then run into the first P. C. C., where the instrument was set and the compound curves to E. C. run in in the same manner as from B. C. to the body of the curve.

I think, however, I would prefer the curve $y = ax^n$ proposed by Mr. Woodman, but to locate it, points in the curve should be obtained by computed angles from the tangent. It is neater than the offset system. The length of the semi-tangent corresponding to certain radii should also be computed. In other words, there should be tables corresponding to those I have described for flattening by compound curves, in order that ordinary locating engineers may be able to use them.

Professor Airy, of England, proposed the cubical parabola for all railroad curves, and the entire abolition of circular curves. I believe he claimed for the cubical parabola that it was the only curve besides the circle that could be easily run out instrumentally. It was discussed in *Van Nostrand's Magazine* about the year 1869.

I do not think, however, that any curve will ever supersede the circle for railroad curves, whatever may be done in trimming its ends.

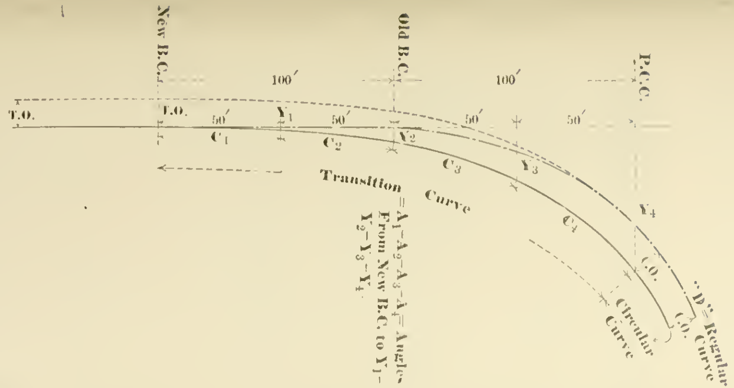
Mr. W. J. Wilgus (Member).—I am glad to see that Mr. Woodman has brought before the Society, for discussion, a subject that has thus far been too much neglected by engineers.

There are two defects in the almost universal practice of circular curves on railroads, and these involve discomfort to the passengers and expense of maintenance. These defects could easily be remedied during the original construction, by use of the transition curve. They are (1) the superelevation of the outer rail on the tangents at each end of the curve, causing uncomfortable tipping of cars approaching and leaving the latter, and (2) the sharp shock experienced on passing from the tangent to the circular curve, or *vice versa*.

The transition curve not only obviates any shock by tapering or spiraling the curve from the tangent to the regular circular curve, but also permits the elevation of the outer rail to start at the point of transition on the tangent, and to increase regularly until the required maximum elevation is attained at the point of the regular circular curve; thus obviating any necessity for superelevating the outer rail on the tangent.

The principal reason why the transition curve has not been more extensively used, is that most of the methods proposed have been cumbersome and have required too much mathematical work by the field engineer, who preferred to "let well enough alone" and to use the plain circular curve rather than bother his head with abstruse problems requiring rapid solution in the field.

To overcome this difficulty, I calculated several years ago the following table of transition curves:



D. ° ′	R.	T. O.	C. O.	Y_1	Y_2	Y_3	Y_4	C_1	C_2	C_3	C_4	A_1 ′	A_2 ° ′	A_3 ° ′	A_4 ° ′
1 00	5729.6	0.29	0.29	.02	.11	.49	1.16	50.00	50.00	50.00	50.01	1	5	11½	0 20
1 30	3819.8	0.43	0.43	.03	.21	.73	1.74	50.00	50.00	50.00	50.01	2	8	17½	0 30
2 00	2864.9	0.58	0.58	.04	.29	.98	2.33	50.00	50.00	50.00	50.02	3	10	23	0 40
2 30	2292.0	0.72	0.72	.05	.36	1.22	2.91	50.00	50.00	50.00	50.03	3	13	28½	0 50
3 00	1910.1	0.87	0.87	.05	.43	1.47	3.49	50.00	50.00	50.01	50.04	4	15	34	1 00
3 30	1637.3	1.01	1.01	.06	.50	1.71	4.07	50.00	50.00	50.01	50.05	4	18	39½	1 10
4 00	1432.7	1.16	1.16	.07	.58	1.96	4.65	50.00	50.00	50.02	50.07	5	20	45	1 20
4 30	1273.6	1.30	1.29	.08	.65	2.20	5.24	50.00	50.00	50.02	50.09	6	22½	50½	1 30
5 00	1146.3	1.45	1.44	.09	.72	2.45	5.82	50.00	50.00	50.03	50.11	6	25	56	1 40
5 30	1042.1	1.59	1.58	.10	.79	2.69	6.40	50.00	50.00	50.03	50.13	7	28	1 02	1 50
6 00	955.1	1.74	1.73	.11	.87	2.95	6.98	50.00	50.01	50.04	50.16	8	30	1 08	2 00
6 30	882.0	1.88	1.87	.12	.94	3.19	7.56	50.00	50.01	50.05	50.19	8	33	1 13½	2 10
7 00	819.0	2.02	2.00	.13	1.02	3.44	8.14	50.00	50.01	50.06	50.22	9	35	1 19	2 20
7 30	764.5	2.16	2.14	.14	1.09	3.68	8.72	50.00	50.01	50.07	50.26	10	38	1 24	2 30
8 00	716.8	2.30	2.28	.15	1.16	3.93	9.30	50.00	50.01	50.08	50.29	10	40	1 30	2 40
8 30	674.7	2.44	2.41	.16	1.23	4.17	9.88	50.00	50.01	50.09	50.33	11	43	1 35½	2 50
9 00	637.3	2.58	2.55	.17	1.31	4.41	10.46	50.00	50.01	50.10	50.37	11	45	1 41	3 00
9 30	603.8	2.71	2.67	.17	1.39	4.65	11.04	50.00	50.01	50.11	50.41	12	48	1 46½	3 10
10 00	573.7	2.84	2.80	.18	1.45	4.89	11.62	50.00	50.02	50.12	50.45	13	50	1 52	3 20
10 30	546.4	2.98	2.94	.19	1.52	5.13	12.20	50.00	50.02	50.13	50.50	13	53	1 57½	3 30
11 00	521.7	3.11	3.05	.20	1.60	5.38	12.78	50.00	50.02	50.14	50.55	14	55	2 03	3 40
11 30	499.1	3.23	3.16	.21	1.67	5.62	13.35	50.00	50.02	50.15	50.60	15	58	2 08½	3 49
12 00	478.3	3.36	3.29	.22	1.74	5.87	13.93	50.00	50.02	50.17	50.65	15	1 00	2 14	3 59
12 30	459.3	3.49	3.41	.23	1.82	6.11	14.50	50.00	50.02	50.19	50.71	16	1 03	2 20	4 09
13 00	441.7	3.63	3.54	.24	1.88	6.36	15.08	50.00	50.03	50.20	50.76	16	1 05	2 26	4 19
13 30	425.4	3.75	3.64	.25	1.95	6.60	15.66	50.00	50.03	50.22	50.82	17	1 08	2 31½	4 29
14 00	410.3	3.87	3.75	.26	2.02	6.85	16.24	50.00	50.03	50.23	50.88	17½	1 10	2 37	4 39

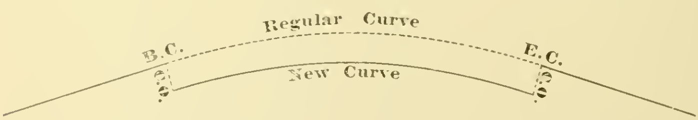
This table has at least the merit of simplicity. It is based on the principle of the cubic parabola, and the transition for any curve up to 14° can be easily laid out with either the tape or the transit. The *modus operandi* is as follows: Given a tangent, and say a 4° curve at which a transition curve is desired, establish a point on the tangent 100 feet from the old "B. C.," and call it the new "B. C." or station "O" of the transition curve. Set up the transit at the latter point and deflect from the tangent as follows:

0 + 50	. . . .	0° 5′	A_1.
1 + 00	. . . .	0° 20′	A_2.
1 + 50.02	. . . .	0° 45′	A_3.
2 + 0.09	. . . .	1° 20′	A_4.

The latter station will be the point of compounding with a circular curve, parallel to the regular 4° curve, and 1.16′ (C. O.) inside of it. If preferred, the ordinates from the tangent produced, Y_1, Y_2, Y_3 and Y_4, may be measured with the tape, instead of turning off the angles, A_1, A_2, A_3 and A_4, as shown in the figure.

The original circular curve should be run out with the temporary points, and the points on the inside parallel curve should be located therefrom by using the distance given in the column (C. O.). In some cases it may be easier to set the tangent "out," instead of the curve "in," in which case the tangent offset, given in column (T. O.) should be used in place of the curve offset (C. O.). Data for curves other than those given in the table, can be obtained by interpolation.

In the original location the line can be located as usual, employing circular curves, but when the stakes are set for grading they should be placed on curves, thus:

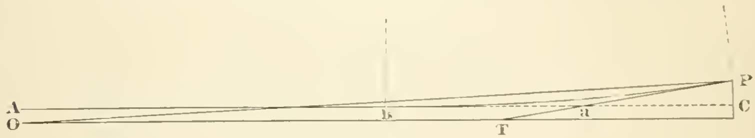


When centers are given, the transition curves can be set with the aid of the table without any other calculation.

The length of the transition curve, 200 feet, was chosen as giving plenty of distance in which to attain the maximum permissible elevation of say five inches, without unduly lengthening the curve.

All the curves on the R. W. & O. R. R. were originally circular; but we are inserting transition curves wherever it is possible without incurring too great expense; and the greater ease with which our trains ride the curves and the decrease of work to keep the track in line, amply justify the expenditure.

J. S. Sewall, M. Am. Soc. C. E.—Instead of assuming a constant value for a in the equation $y = ax^n$ as in Mr. Woodman's very valuable paper, a transition curve may be fitted to a circular curve by assuming a given length for the portion of curve to be replaced by the transition curve. This method I used twenty-three years ago when putting in lines for the track from Hudson to Stillwater Junction and Stillwater.



Let $l = PB$ be the length of the portion of circular curve to be replaced by a transition curve, and CBA its tangent. Let a be angle of arc PB. Make angle $OPT = \frac{2}{3}\,a$ and $BO = l$. Angle POT will equal $\frac{1}{3}\,a$. Any point p on the transition curve may be set with the transit from O, making angle $pOT = \frac{1}{3}\,a \times \frac{pO^2}{4l^2}$; that is to say, making angles from OT proportional to the square of the distance pO. The departure of the transition curve PB will be the same as the departure from OT, and points may be set from P by making the angle $pPT = \frac{1}{2}$ arc $pP - \frac{1}{3}\,a \times \frac{pP^2}{4l^2}$. This method may be used for curves of 10° or less, l being not more than 100 feet for a 10° curve. The curve will not appreciably differ from a cubic parabola.

When it is more convenient to put in a curve by offsets, or when required for larger arcs, make $AO = \frac{1}{3}\,PC$; make ordinate at distance l from either end $= \frac{1}{2}\,AO$, and other offsets proportionate to the cubes of their distances from O. If the arc is larger than 10°, put in points from curve PB for distance l from P, in proportion to the cube of the distance from P. This method may be used for any length or degree of curve, up to a quarter circle.

This curve increases its curvature uniformly in proportion to the distance from O, and corresponds to a uniform increase in the elevation of the outer rail from nothing at O to full elevation at P.

If a sharper transition curve is desired, the curve $y = ax^4$ may be put in (for small arcs), making angle $OPT = \frac{3}{4}a$, $POT = \frac{1}{4}a$, $BO = 2l$, angle $pOT = \frac{1}{4}a \times \frac{pO^3}{27l^3}$, AO will equal $\frac{1}{2}PC$, and the ordinate opposite B from OT will be $\frac{16}{27}\,AO$.

Mr. C. L. Annan (Member).—In *Engineering News* for March, 1882 (Vol. IX, pp. 78 and 126), there appeared an article on spiral

curves by Mr. W. H. Fry. It seemed to offer a good system, and I prepared a simple table for its use on the Sonora Railway. A circular of instruction to field engineers was issued by the Chief Engineer, and the matter dropped.

The length of spiral, at each end of curves of all degrees, was only 100 feet. This seems to be about as long as is practicable for lines on which curves are separated by short tangents, as on mountain and river roads.

The Searles Spiral was introduced on the location of the Northern Division of the Mexican Central Railway in the summer of 1883.

President Wilson.—In an article on The Sickle or Perfect Railway Curve, by Mr. D. E. Hughes, published in the *Transactions of the Technical Society of the Pacific Coast*, Vol. IX, p. 63 (1892), the equations of the curve are deduced, the practicability of its application is shown and a full table of functions is given.

Up to 21° 20′ of curvature the curve is practically a cubic parabola.

November 5, 1894.

The Secretary.—Since our last meeting I have asked several railroad engineers for their views upon the subject of transition curves. I submit a few quotations from the replies received:

Mr. W. H. Earl, Resident Engineer of the Atchison, Topeka & Santa Fé Railroad, at Newton, Kas., says, in effect, "Transition curves have never been used on this road. Consequently I have given the matter no attention. We have more than we can properly do with our present force, to take the line as we find it. I now have some 1900 miles to look after."

Mr. M. W. Wambaugh, late Chief Engineer of the Gulf, Colorado & Santa Fé Railway, Galveston, Tex., says, "I have never used transition curves, nor have I seen a piece of track under them. Personally I think they cannot be made practically useful while maintenance of track is under the direction of the present class of roadmasters. Given a track under the complete control of an engineering department, I am of the opinion that with perfected drainage and full ballast, transition curves would materially add to the life of the rail and reduce expenditure of power. I do not believe they can be maintained without the constant intelligent supervision of practical civil engineers occupying positions as roadmasters."

Mr. C. W. Sanders, of Los Angeles, Cal., says, "The Atlantic & Pacific Railroad used easement curves through the mountains. They

eased up on each end by a series of short curves, each of which had half the degree of curvature of the next one. For instance, a long 12° curve would have from tangent points on each end 100 feet of 1° 30′ curve, 100 feet of 3° curve and 100 feet of 6° curve to the main 12° curve. A shorter 12° curve would be eased by curves 50 feet in length.

The *Technograph*, No. 5, of 1890–91, gives, on page 77, a good article on Transition Curves, by A. N. Talbot.

Mr. Chas. Harlowe, M. Am. Soc. C. E., writes from Centralia, Wash.: "I have used transition curves since 1880. My method, however, has been to use only a light circular curve at the ends of curves over 6°. This saves considerable trouble in the drafting room. It is absurd to go to the refinement of spirals, when the first time the eye of the gentleman from Erin or Scandinavia gets onto it, the curve will be put in to suit him. I have been told that the Southern Pacific sets stakes and requires the track to be kept to them."

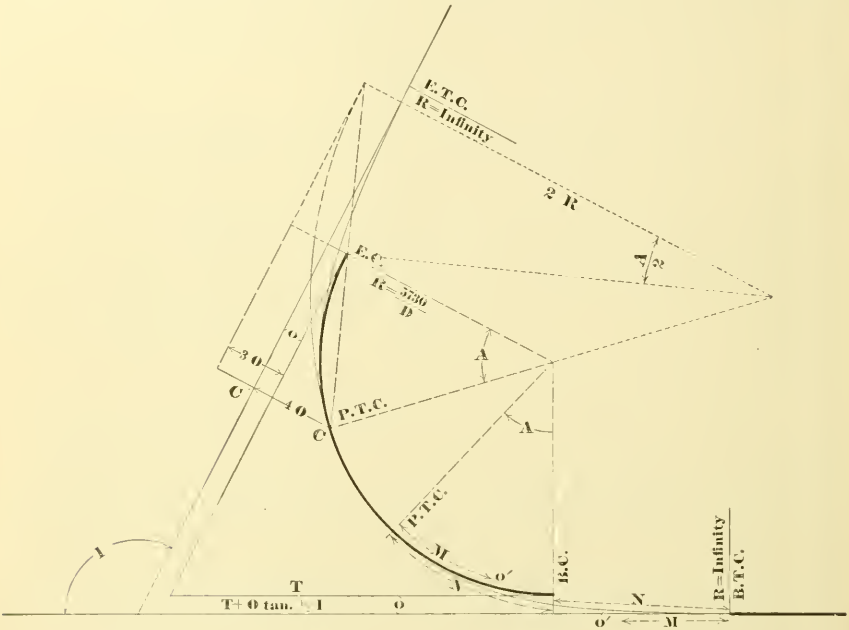
Mr. R. R. Coleman, Superintendent of the Santa Fé, Prescott and Phœnix Railway, at Prescott, A. T., who has had a vast experience in charge of tracklaying, says, "My only experience with transition curves was on the El Paso branch (Atchison, Topeka & Santa Fé System) in 1885. I had charge of the track after it was built, and, owing to numerous changes in section foremen and trouble in keeping P. C. C's. located, I found it somewhat difficult to keep curves properly aligned and elevated. These faults, of course, are not with the curves but with the track department. I would like to see or hear of a thorough test having been made on some first-class road where track is kept up to a high standard and under the supervision of the engineering department."

Mr. Samuel Rockwell (Member).—The following rule for putting in transition curves was prepared when I was about to undertake a piece of location requiring a large amount of sharp curvature to be run in by a number of different transit men. It was intended to be within the easy comprehension of all, and also to make it just about as easy to run in all curves with transitions, as without.

The transition curve here given, is the one of which A. M. Wellington began a discussion in *Engineering News* for February 8, 1890, and its general properties are therein described and discussed by him; but, so far as I know, he never deduced a practical method of using it, which would appeal to the average transit-man with sufficient force to convince him of its easy application in the field.

Mr. Wellington describes this curve as: "A curve which, starting

with an infinite radius at the P. C., has a degree at every point in direct proportion to the distance from the P. C, until at the P. T. C., where it connects with and becomes tangent to the main curve, it is of the same degree as that curve."



"N" = ½ length of transition curve $= \frac{A}{D}$, the additional length to be added to the end of the circular curve, or to be taken from the minimum tangent allowed between two curves, was assumed to be the most desirable independent variable, and the table was made to cover probable values to be assumed for it. The table, rule, figure, and formulæ were then furnished in convenient form for insertion in all field books.

This rule, besides having fully come up to expectation on location, has been used with equal satisfaction in realigning many of the main line curves on the Lake Shore & Michigan Southern Railway, during the last two years. For this work a survey of the old curve is platted to scale, and on this plat, a curve with suitable transition is fitted by trial, and for curves no sharper than 4°, it is generally found that the new curve can be so fitted that the total amount of throwing will be little more than would be necessary if the original circular curve had been re-run and the track thrown to it. The length of " N " is varied to suit conditions, almost covering the limits of the table, but the value most

TABLE OF TRANSITION CURVES.

Giving offsets for connecting a one degree curve with a tangent by adding 50′, 100′, 150′, 200′, 250′ or 300 feet to each end of curve.
Offsets are given for each 25 feet (measured along the curve) from either end of transition curve to its middle point.
Offsets for any curve other than one degree are found by multiplying offsets given by the degree of Curve.

O = total offset.
O' = offset at any point M from either end of transition curve.
A = angle thrown out from circular curve = angle of transition curve.
D = degree of circular curve.

$N = \frac{1}{2}$ length of transition curve $= \frac{A}{D}$.

$$O = \frac{3820 \; sin^2 \; \frac{1}{2}A}{D} = \frac{N^2}{6R}$$

$$O' = \frac{m^3}{n^3} \cdot \frac{O}{2}.$$

Increased Length of Curve at either end $= N$.	Total Offset $O = \frac{N^2}{6R}$	Offsets O' for Successive Values of M. M = Distance from End of Curve.											
		25	50	75	100	125	150	175	200	225	250	275	300
50	0.073	0.004	0.036										
100	0.291	0.002	0.018	0.061	0.145								
150	0.654	0.001	0.012	0.041	0.097	0.189	0.327						
200	1.163	0.001	0.009	0.031	0.073	0.142	0.246	0.390	0.582				
250	1.818	0.001	0.007	0.025	0.058	0.111	0.196	0.312	0.465	0.663	0.909		
300	2.619	0.001	0.006	0.025	0.049	0.095	0.164	0.256	0.388	0.553	0.757	1.008	1.309

To lay out a transition curve, measure from vertex along the tangent a distance $T' = T + O \; tan \; \frac{1}{2} I = (R + O) \; tan \; \frac{1}{2} I$. At this point make an offset O obtained from the second column in above table corresponding to the desired value of N (increased length of curve as shown in first column of table) to the $B\,C$ of circular curve. Locate the $E\,C$ of circular curve in the same manner and run in the curve from $B\,C$ to $E\,C$. The middle point of this offset will be the middle point of the transition curve. Measure from this middle point, a distance N as above to the point $B\,T\,C$ on the tangent and to the point $P\,T\,C$ on the circular curve. From the two ends of the transition curve thus established, lay off intermediate points on the transition curve by offsets from the tangent and circular curve respectively, as found from the table for given distances M from these ends of the curve.

commonly used is about 150 feet, and is to a considerable extent independent of the degree of the curve. In all cases, the superelevation of the main or circular curve is gained rigidly on the transition curve, the track being level at the B. T. C., and having the full superelevation at the P. T. C., and these points are plainly shown by stakes properly marked. Stakes for aligning track on transition curves are ordinarily set every 50 feet.

There is no doubt that good riding track demands transition curves, and, once it is realized that the terrors of their mathematics can be escaped by simple rules, they will surely come to stay.

Mr. W. A. Truesdell (Member).—I am satisfied that spiral curves, by causing delay, would prove an obstacle on location. Moreover, they would be inconvenient in office work. Some simple, practical form of transition is the only thing that would be tolerated, and this is wanted principally on roads already built. On these, I would flatten the curves at the ends by compounding with circular curves so as to move the track the least possible out of its position on the roadbed. A 3° curve 1,000 feet long could be so compounded as to have 100 feet of 1° curve and 100 feet of 2° curve on either end without moving the track more than one foot out of the original line. The track should be laid to this alignment, but the office map should show a simple 3° curve.

M. D. Rhame (Assistant Engineer, Northern District, Chicago, Milwaukee & St. Paul Railway).—I am heartily in favor of the transition curve and am using it in the Northern District whenever we re-run the old curves.

We commenced to use it three years ago, and we have used it to some extent on several divisions. The results are very satisfactory. The superintendents and roadmasters are well pleased.

Not only does the curvature of the spiral increase gradually and regularly between the tangent and the circular curve, but it enables us to increase the elevation of the outer rail gradually and regularly, and at every point to have the elevation in proportion to the degree of curvature. This is mathematically impossible when the change from a tangent to a circular curve is abrupt, whether the elevation is made wholly on the tangent, wholly on the curve, or partly on each. Our former custom was to start back on the tangent and get a full elevation at the beginning of the curve. It is obvious, I think, to any one, that the spiral must give better results, and actual practice proves it beyond a doubt. We use Searles' method, as given in his "Railroad Spiral" Mr. F. E. Rice, my associate, who is here this evening, can speak of the field work from the standpoint of actual practice.

Mr. F. E. Rice.—I am opposed to the use of compound curves in lining up old track. I find that in re-running old curves, it is as easy to use the spiral on a simple curve as to leave it out, and the labor of lining track is as often lessened as increased by its use, while the results are much more satisfactory.

Mr. W. L. Darling (Principal Assistant Engineer, Eastern Division, Northern Pacific Railroad).—Almost any form of easement curve will do, if it is properly adapted. The general formula should be flexible, and the tables so far extended that the most frequent of the special problems can be solved with as little field work as possible. Generally, the cost of the engineer's service in adjusting some special curve is infinitely small as compared to the amount saved in changing track. The Northern Pacific has adopted the Searles spiral, which has been in use on that system for four years. Blue prints of detailed instructions and full tables of spiral tangents and long chords, for chords increasing by 1 foot from 10 feet to 50 feet, are furnished to all assistant engineers.

Mr. K. E. Hilgard (Member).—Mr. Woodman's method seems practical and simple, as far as it goes, and probably it is quite satisfactory and serviceable in laying out new work. In applying it to the improvement of existing track, there are, however, two practical requirements which seem to be lost sight of: (1) To avoid the cutting of rails, which will be necessary if the length of the improved line differs from the length of the original line; and (2) It is essential that the old circular curve and its eased substitute shall approach coincidence as near as possible, especially on high banks, in deep cuts and over permanent structures. To obtain these results the one curve must intersect the other in at least two points. With this object in view, the well-known Searles spiral has been adopted on the Northern Pacific Railroad. If Mr. Woodman's method can be similarly adapted without sacrificing its simplicity, I think its practical value will be considerably increased.

Mr. S. D. Mason (Member).—We all recognize the desirability of easing the ends of railroad curves, and the need of a simple practicable formula to follow in securing this end. It seems to me that one advantage of the system under discussion is, that when the degree of the main curve is known, the kind of transition curve is also known, and this is of benefit in re-lining track. I think, too, that this system can readily be applied to the easing of curves in old track originally laid with simple curves. I have always held the opinion that some form of the parabola was the proper curve to start with from a tangent, and one that could be easiest laid out in the field by offsets.

Mr. A. M. Haynes, C. E. (Visitor, from Mankato, Minn).—I would suggest to Mr. Truesdell that he could locate as many miles of line in a day with transition curves as without.

I wish to defend the trackman, who seems to be getting it from all sides. If the engineer will do the grading, and will lay the track on proper curves, I believe they will stay there. I think the method of offsets is out of the question. Mr. Wellington, the father of that plan, says, in an editorial, *Engineering News*, October 5, 1893, that there is no "satisfactory system" of transition curves. Mr. Searles' method is in the right direction, but is too complicated.

The following (corrected) from the *Engineering News* of June 14, 1894, briefly described my plan:

"A UNIVERSAL RAILWAY SPIRAL."

"A correspondent sends us a neat method of laying out a spiral curve, based upon a spiral calculated to suit a 1° curve, using 100-foot chords. For other than an approach to a 1° curve, chords are used of lengths inversely proportional to the degree of the curve, the method being identical with that for handling circular curves. Thus, for a 5° curve, the chord lengths would be one-fifth of 100 feet, or 20 feet. The following table locates the spiral for a 1° curve with 100-foot chords and a central angle of 3° 30′, the same for all curves:

0	1	2	3	4	5	6
*	0°05′	0°12½′	0°23⅓′	0°37½′	0°55′	1°16′
0°05′	*	0°10′	0°22½′	0°38⅓′	0°57½′	1°20′
0°17½′	0°10′	*	0°15′	0°32½′	0°53⅓′	1°17½′
0°36⅔′	0°27½′	0°15′	*	0°20′	0°42½′	1°08⅓′
1°02½′	0°51⅔′	0°37½′	0°20′	*	0°25′	0°52½′
1°35′	1°22½′	1°06⅔′	0°47½′	0°25′	*	0°30′
2°14′	2°00′	1°42½′	1°21⅔′	0°57½′	0°30′	*
Offsets, 0	.14	.73	2.00	4.40	8.00	13.20

Deflections are given from tangent at each point designated thus * to all other points.

To find tangents (Ts), long chords (Cs) and externals (Es) for the combined circular 1° curve with spirals, having given the whole angle (I), tangent (Tc), long chord (Cc) and external (Ec) for a circular 1° curve without spirals.

(1) $Ts = Tc + 249.92 + 2.50 \tan \frac{1}{2} I.$

(2) $Cs = 2\, Ts \operatorname{Cos} \frac{1}{2} I.$

(3) $Es = Ec = 2.50 \div \cos \frac{1}{2} I.$

For other than 1° main curves, each of these and other functions are inversely proportional."

I use the same spiral that Mr. Searles uses, but with only six chords, located by the same six deflections; but the chord length varies with the degree of the main curve. Mr. Searles (like all other writers) treats the spirals independently of the main curve. I think that is the reason why the almost unanimous verdict of practical men is that transition curves are much desired but impracticable. The spiral and the main curve should be taken as a whole; and this is the idea I wish to make prominent. No plan will ever be successful without this ready means of finding these functions of the *combination*. They are necessary for accurate platting if not for locating on the ground. The locating engineer should never bother his head about spirals. Only instruct the transit-man to use standard spirals, and all will go automatically. The transit-man pastes this little table of deflections in the back of his book, and inserts the necessary figures (found by three simple formulas) into his curve tables, which have to be added when transition curves are used, and he is thoroughly equipped. No books are wanted on the subject. This may seem a too decided tone. I do not wish to be understood as setting myself up as an authority on the subject. These are simply my firm convictions, and I am anxious to hear other views, and ready to learn from them.

The polar equation of this curve is

$$\theta = 2a\left(\frac{r^2}{6} + \frac{r}{4} + \frac{1}{12}\right).$$

where θ is the deflection angle from tangent at P. C.

a = the deflection angle for the first chord, = 5′ in my spiral.

r = radius vector, or number of chord lengths.

The second differential coefficient of this general equation $= \frac{2a}{3}$.

This affords a much neater method than that employed by Searles in constructing tables of deflections.

I have explained this spiral to Mr. Fernström, Chief Engineer of the Chicago Great Western Railway, and he intends to give it a trial.

Mr. W. R. Hoag, C. E. (Professor of Civil Engineering, University of Minnesota).—The economic worth of the transition curve has never been questioned by the railroad world. An examination shows that accidents are twice as likely to occur on curves as on straight track,—a large part of this extra hazard comes from interference with the natural motion of the train by the curved line of the track. The very slow adoption of the remedy to this recognized evil cannot be attributed to the absence of sufficiently well formulated schemes to correct it, for the profession has a half dozen elaborate plans to that end.

The idea seems to have been to furnish an almost rigidly exact plan

for an engineer to adopt and execute; whereas, what railroads to-day need, is a plan, plain and fundamental in its make-up, avoiding exact relations, not *per se*, but from the complexities which accompany; which plan can and will be readily understood and carried into execution by that part of the railroad fraternity having this work in charge.

The plan here presented by Mr. Woodman stands in strong contrast, in this regard, with the more complicated systems with which I am acquainted and which I have used with my classes in railroad curves at this University. I am using Mr. Woodman's system this year in place of more elaborate plans, for I believe that our students get enough of abstruse mathematics in other lines of their work.

The manner in which this plan is presented is natural and easy to follow and understand, and its approximations are safely within the possibilities of execution.

The replies received from a number of railroad officials showed, to my mind, that the general opinion of the fraternity, touching the transition curve, indicates not so much a disregard of its economic worth as a hesitation to grapple with its difficulties. Scarcely one, if I remember rightly, addresses himself to the specific question as to the merits and demerits of the plan presented.

I believe the simplicity of the plan will do much to aid in the adoption of the transition curve on our railways.

An example, taking up a case of usual occurrence, and carried through, step by step, giving exact field methods of execution, would, if taken up by the author, supply what we are obliged to do.

Mr. Annan.—Two brief observations this evening have renewed my appreciation of the fact that the practical section man has been called upon to shoulder a responsibility to which the average engineer in charge of railroad work has been unequal. Intuitively the one has eased the curves regardless of the stakes of the other. It seems to me that Pat and Ole have some little reason to set the eye against the instrument when no provisions have been made for easement.

Mr. Dunn, the roadmaster, said, "I line up my track to the best of my judgment, and then I test my work by riding over it." Mr. Rice related that he asked the foreman why he didn't follow the stakes. "I did, at first, but then I got orders to put the track in such shape that a train could go over it."

If a trackman can make a train ride fairly well on a bank in bad alignment, what might he do, even without stakes, on a properly constructed roadbed?

Engineers having under supervision track aggregating over 10,000 miles, all, in fact, who have spoken from practical experience, have pro-

nounced before us their belief in the practicability of the transition curve. This accords with the statement of Mr. E. L. Woodley, who, in *Engineering News*, Vol. XXIV, page 401, says:

"I feel safe in making the assertion that there is no road in the country where they have been introduced that would now think of building a railway involving what might be considered even moderately sharp curvature without the use of spirals."

He recommends as a text-book: "The Railroad Spiral," by Prof. D. M. Greene.

Mr. Woodman.—In closing the discussion of what has been abundantly shown to be a live topic, commanding widespread attention among engineers, I would first express my hearty appreciation of the thought of others. Mr. Sewall's early use of transition curves is especially interesting, and quite in keeping with the reputation of that veteran engineer. Mr. Darling's adaptation of the Searles spiral to the requirements of his own practice; the methods employed by Mr. Wilgus and Mr. Rockwell, and that proposed by Mr. Haynes; the book by Prof. Crandall that has been mentioned, and the papers by Prof. Robinson, in *Van Nostrand's Magazine*, some years back, all display an attractive ingenuity in dealing with the subject. A comparison of these writings discloses an interesting diversity of conditions applied to the problem. Confining my remarks to those who have taken part in the discussion, Messrs. Sewall, Rockwell and Wilgus make the transition twice as long as the curve it displaces. This is a rational and flexible method. But I should question the expediency of the proposal of Mr. Haynes, in which a very long transition is provided for a light curve, and a very short one for a sharp curve, because I consider it better practice to apply a short transition to a curve so light as scarcely to require one at all, and on the other hand a long one to a curve as sharp as ten degrees. If we take the trouble to put in transitions, I think we shall be drawn to a considerable length for all cases; for the light curves, because they are the most numerous and therefore will contribute most to improved track, and for the sharp ones, because they most certainly require it.

I will add a few words on the point raised by Mr. Hilgard, the adaptability of the transition curves of the paper to circular curves in existing tracks, which will be by far the most extensive application of any such device. I think they will suitably meet this need, though I purposely restricted the paper to general principles. Here we are of course often hampered by the condition that the line must not be moved far. To take an extreme case, suppose we have sixty degrees of ten degree curve in track. In order to ease the ends of this curve we must sharpen it in the middle. Beginning at the middle of the curve, say that

we run a 10° 30′ curve for 25° each way. This will leave 5° to go into the transition. The end of the line run will be 2.48 feet inside of the old line, and 5.75 feet distant at right angles from the tangent on which we intend to close. Take from the third table the transition that consumes 5° of angle. Its terminal radius is that of the 7° curve. Its terminal y is 4.70 feet, which, taken from 5.75 feet, shows that the new curve is to be moved outwardly, at the middle point, a distance = 1.05 feet divided by the sine of 60°. Thus the new line will lie 1.2 feet outside of the old curve at the middle point, and 1.3 feet inside at the ends, cutting the old line in two places. The reader will understand that this is a mere illustration, and that, instead of the 10° 30′ curve, a different one might be used, or, instead of a simple curve a compound one, with the result of approaching the original curve more nearly, if that should seem desirable.

And there is an alternative course to the one just outlined, which is to change the value of a and compute a new transition for the particular case. In equation (7) a is 0.22 feet for one station taken as a unit of length. If this value be doubled, the numerator of the fraction in (7) will be halved. That is, the curve will be made sharper, we shall find a given short radius at a less distance from the origin, and our terminal y and the other elements will be smaller. In this way we may design a curve that will end in a given radius and make a smoother transition than the one found in the preceding paragraph, based upon the limited scope of our ready-made tables. As to all special cases, every engineer will wish to work out his own tables.

It is only with the sharpest curves that either of the foregoing expedients will be necessary. This is shown by the small values contained in the last column of the third table. Where the change in the position of the line is slight, the track can be thrown to the new line without cutting rails, the transition simply taking up a part of the old tangent. But if a case should arise, in which the difference in length of the old and new lines presented a difficulty of this nature, the transition could be made of such length as, being added to the length of the new circular curve, would make a certain number of rail lengths more than the length of the original curve, and thus no rails need be cut.

TESTS OF CEMENT JOINTS FOR PIPE SEWERS.

By Freeman C. Coffin, Member of the Boston Society of Civil Engineers.

[Read June 20, 1894.*]

In a separate system of sewerage the infiltration of ground water is a matter of serious importance, especially where the effluent has to be pumped, or treated either chemically or by filtration; and, even in a system where the disposal is by gravity and without artificial treatment, this infiltration is an annoying element to the designer, on account of the uncertainty of the quantity with which he has to deal. If it could be approximately known in advance how much ground water must be provided for, it would usually be a matter of small moment to provide pipes large enough to carry it, but in a self-cleansing system it is nearly as important to have the sewers small enough as it is to have them large enough. It is well known that there is more or less leakage of ground water in all systems of pipe sewers, and in some cases it is a large percentage of the capacity of the system.

Undoubtedly this leakage is largely caused by the fact that it is difficult, if not impossible, to make perfect joints in a wet trench. By a perfect joint I mean one that is completely filled all around with cement. This difficulty is greatly increased by the shortness of the lengths of pipe; and the narrowness of the joint room in the so-called standard form of joint adds to the difficulty of filling it with the cement mortar, especially when, as is often the case, the pipes are not concentric.

It is customary to overfill these joints, making an angle of about 45° between the outside face of the cement and the side of the pipe. This assists in preventing the inflow of water, but when the pipes are laid in a trench in which water is present, it is nearly impossible to keep the mortar intact until it is set. The shortness of the pipe—not exceeding three feet—makes it very hard to dig a bell hole large enough to work in and to provide for the suction of a pump, while still keeping the pipe in proper alignment; and the water cannot so well be dammed back while the joint is being made, as in a longer one, such as a water pipe.

The Portland Stone Ware Co. has recently begun the manufacture of sewer pipes with wider and deeper sockets, under the name of "deep socket" pipe. The shape of this socket is shown by Figs. 4 and 5, and the standard socket is shown by Figs. 2 and 3. All four figures represent

* Copy received December 13, 1894.—*Secretary Ass'n Eng. Socs.*

joints for 6 inch pipe. It is hoped that the use of these joints will facilitate the execution of better work. The city of Brockton has used this pipe in its new sewerage system. The following table gives the dimensions of these joints from 4 to 24 inches in diameter.

TABLE OF DEEP SOCKET PIPE.

Size.	Depth of socket.	Thickness of joint room.
4	2 5-8 inch	5-8 inch
6	2 5-8 "	5-8 "
8	2 5-8 "	5-8 "
10	2 5-8 "	5-8 "
12	2 5-8 "	5-8 "
15	3 1-8 "	5-8 "
18	3 1-8 "	5-8 "
20	3 1-8 "	5-8 "
24	4 "	5-8 "

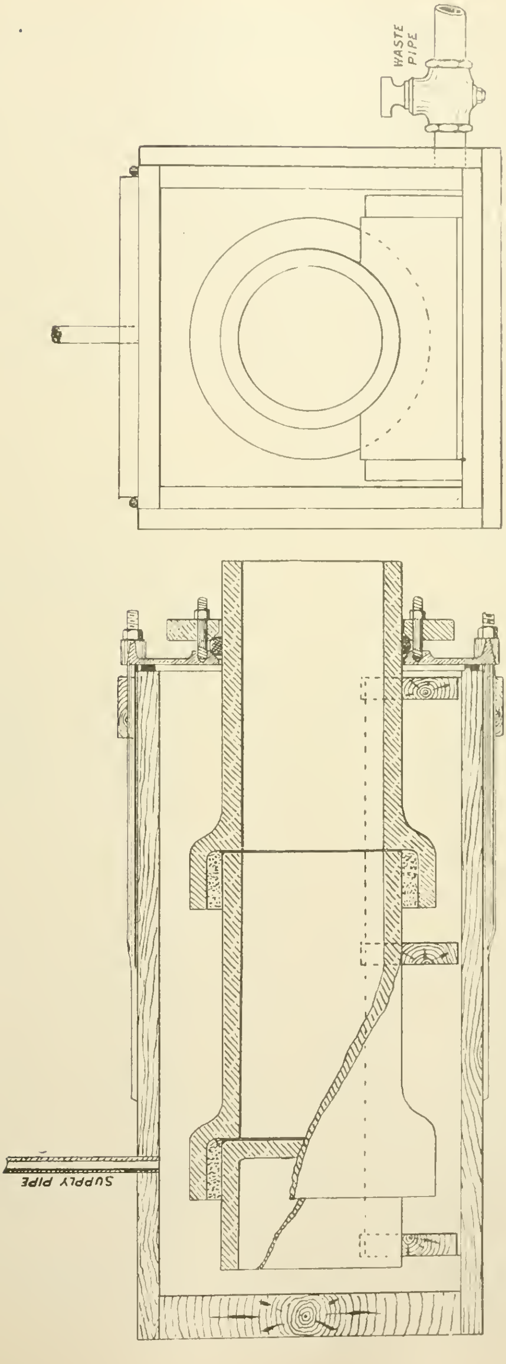
For two or three years I have been contemplating the making of some tests upon cement sewer joints, and this fall I concluded to undertake it in order to ascertain, if possible, the relative amount of leakage, or rather seepage, of water through well-made joints, and in the hope of gaining some knowledge of the results to be secured by the use of different forms of joint and of different kinds and mixtures of cement. It was not practicable to reproduce the exact conditions to which the joints are subjected in the trench, but in order to approximate them as closely as possible, I made a tank, as shown in Fig. 1, in which the pipes could be placed with one open end projecting, and with the joints under water pressure from the outside, as in a sewer when the ground water is higher than the pipe; the leakage to be carefully collected from the projecting open end of the pipe.

All of the tests in this tank were made under a uniform head of five feet above the center of the pipe, assuming that this might be nearly an average of the head of ground water. At least it would be a means of comparing the relative values of the different joints in resisting the seepage of the water.

The head was obtained by means of half-inch pipe screwed into the top of the tank, and having at the top a tin pail into which the supply is conducted by a hose. The pail was provided with an overflow in the side by which a uniform head was maintained by allowing a small stream of water to continually run into the pail.

The pipes used were all 6 inches in internal diameter, and in lengths of one foot, made so for convenience in handling. The plug was simply a piece of pipe of the same diameter and six inches long, with a closed end. Fig. 1 shows the pipe and the plugs as they were placed in the tank.

Three forms of joints were tested, viz.: the standard joint, Figs. 2



END ELEVATION (OPEN).

LONGITUDINAL SECTION.

FIG. 1. TESTING TANK.
SCALE, 1/8 FULL SIZE.

and 3; the deep socket, Figs. 4 and 5, and a deep socket with round-about grooves on the inside of the socket and outside of the spigot end of the pipe.

While preparing for these tests I had some apprehension that there might be no leakage in a perfectly made joint under so light a pressure. To have the tests of any value it was necessary to make the joints in as uniform a manner as possible, and therefore as well as could be done, which it was comparatively easy to do with the pipe in a vertical position during the process. Under such conditions it seemed possible, if not probable, that there might be no measurable leakage, and therefore no means of comparing the different kinds of joints; but table 1, which gives a consecutive record of the tests, shows that out of the sixty-three tests only three failed to show leakage, and in these the leakage was not prevented by the use of cement alone.

Figs. 2 and 4.

Flush Joints.

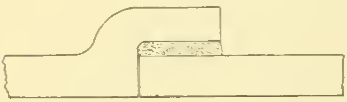


Fig. 2.

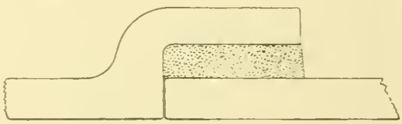


Fig. 4.

Figs. 2 and 3. Standard Sockets.

Figs. 4 and 5. Deep Sockets.

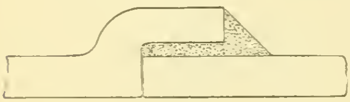


Fig. 3.

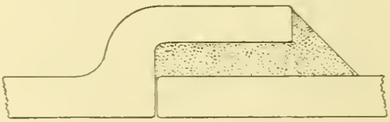


Fig. 5.

Figs. 3 and 5.

Overfilled Joints.

The experiments recorded may be classified somewhat as follows:

I. Kind of Pipe. (*a*) "Standard" Pipe; (*b*) Deep Socket Pipe.

II. Form of Joint. (*a*) Flush Joints, Figs. 2 and 4; (*b*) Overfilled Joints, Figs. 3 and 5.

III. Kind of Cement. (*a*) Rosendale; (*a*-1) neat; (*a*-2) 1 part cement to 1 part sand; (*a*-3) 1 part cement to 2 parts sand. (*b*) Portland; (*b*-1) neat; (*b*-2) 1 part cement to 1 part sand.

IV. Length of Set. (*a*) $1\frac{1}{2}$ hours before putting in water; (*b*) 3 hours before putting in water; (*c*) 6 hours before putting in water; (*d*) 12 hours before putting in water; (*e*) more than twelve hours.

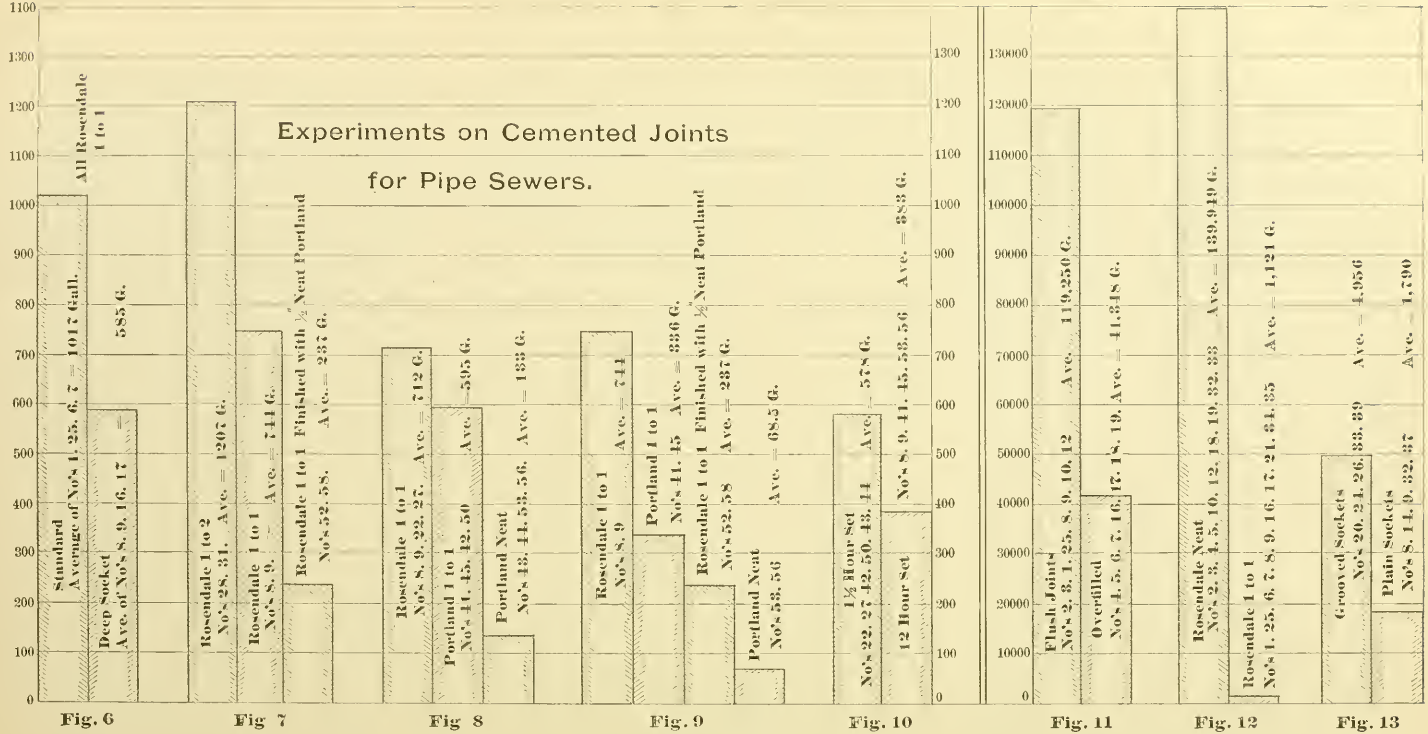
V. Miscellaneous. (*a*) Joint, with jute gasket; (*b*) Joint, with grooved socket; (*c*) Joint, with finish of $\frac{1}{2}$ inch of Portland cement; (*d*) Joint, painted with asphalt.

The experiments were conducted in a light, cool basement, with the temperature in the vicinity of 50° Fahrenheit. They were placed upon end, with the sockets up, and the plug or stoppers in the upper one, two one-foot lengths in each experiment making two joints in each test. The cement was carefully packed into the joints, and rammed with a wooden rammer to compact the mortar as much as possible in the joint. The outside of the joint was carefully smoothed with a smooth tool, a steel table-knife, in fact, this being the most convenient to work with. After the joints were made, they were covered with a damp cloth, which covered the whole pipe to the floor, and were allowed to stand undisturbed in that position until the end of the time of setting. They were then placed upon the wooden cradle, and put into the tank ; the end of the tank and the stuffing-box were placed in position, and the water was let in. The leakage was not collected for measurement until both joints seemed to be running at their full or normal rate, when the time was noted, and the collection commenced. The duration of the tests varied according to the amount of flow and my own convenience, as these tests were mostly made before and after business hours. At the end of the test, the time was noted, and the leakage, measured in a glass graduated to ounces and fractions of ounces.

Table 1 gives a continuous record of the tests in the order in which they were made. Column 7 gives the duration of the test ; column 8, the actual leakage during the test ; column 9, the amount of leakage in cubic feet in one mile of pipe per twenty-four hours at the rate given by column 8 ; column 10 gives the same in U. S. gallons. The leakage through one mile of pipe in twenty-four hours is used as the unit, because all the results are then in whole numbers, and this unit is readily applied to a sewerage system for comparison. The leakage given is on the basis of 2-foot lengths of pipes, or 2640 joints per mile. The tests can be compared with each other in columns 9 and 10, as the results are all reduced to the same basis.

In Figs. 6 to 13, the averages of tests of different classes are compared graphically and numerically. Tests were taken for each of the classes that corresponded in conditions respectively with each other. For instance, in the comparison of Rosendale 1 to 1, Portland 1 to 1 and Portland "neat," Fig. 8, two tests of each with 1½ hours set, and two of each with 12 hours set, have been taken, the form of pipe and joint being the same in all, and each test of one have a corresponding test of the others under like conditions. This was done in all of the comparisons. Otherwise, any comparison of averages would have been misleading.

The following is a brief analysis of the results, as they impressed themselves upon my mind, and as they are supported by the records.


Experiments on Cemented Joints
for Pipe Sewers.
All Rosendale 1 to 1
Standard Average of No's 1. 25. 6. 7 = 1017 Gall.
Deep Socket Ave. of No's 8. 9. 16. 17 = 585 G.
Rosendale 1 to 2 No's 28. 31. Ave. = 1207 G.
Rosendale 1 to 1 No's 8. 9. Ave. = 744 G.
Rosendale 1 to 1 Finished with ½" Neat Portland No's 52. 58. Ave. = 237 G.
Rosendale 1 to 1 No's 8. 9. 22. 27. Ave. = 712 G.
Portland 1 to 1 No's 41. 45. 42. 50 Ave. = 595 G.
Portland Neat No's 43. 44. 53. 56. Ave. = 133 G.
Rosendale 1 to 1 No's 8. 9 Ave. = 744
Portland 1 to 1 No's 41. 45 Ave. = 336 G.
Rosendale 1 to 1 Finished with ½" Neat Portland No's 52. 58 Ave. = 237 G.
Portland Neat No's 53. 56 Ave. = 68.5 G.
1½ Hour Set No's 22. 27 42. 50. 43. 44 Ave. = 578 G.
12 Hour Set No's 8. 9. 41. 45. 53. 56 Ave. = 383 G.
Flush Joints No's 2. 3. 1. 25. 8. 9. 10. 12 Ave. 119,250 G.
Overfilled No's 4. 5. 6. 7. 16. 17. 18. 19. Ave. = 41,348 G.
Rosendale Neat No's 2. 3. 4. 5. 10. 12. 18. 19. 32. 33 Ave. = 139,949 G.
Rosendale 1 to 1 No's 1. 25. 6. 7. 8. 9. 16. 17. 21. 34. 35 Ave. = 1,121 G.
Grooved Sockets No's 20. 24. 26. 33. 39 Ave. = 4,956
Plain Sockets No's 8. 14. 9. 32. 37 Ave. = 1,790
Fig. 6
Fig 7
Fig 8
Fig. 9
Fig. 10
Fig. 11
Fig. 12
Fig. 13

FIGS. 6–13.

The leakages stated are, in all cases, those taking place in twenty-four hours through one mile of pipe in 2-foot lengths.

THE STANDARD PIPE.

In this pipe, a joint made of neat Portland cement with a set of twelve hours, leaked only at the rate of 67 gallons; test, No. 61.

Rosendale 1 to 1, 130 gallons, average of tests 6 and 7; both of these were overfilled. With flush joints, Rosendale 1 to 1 gives 2004 gallons, average of Nos. 1 and 25. Rosendale neat, flush joints, 206,000 gallons, average of Nos. 2 and 3; Rosendale neat, overfilled joints, 162,283 gallons, average of Nos. 4 and 5.

This would show extremely good results with Portland and Rosendale 1 to 1, if it were possible to make joints of good quality in the trench.

Comparing four tests of standard pipe with four of deep socket pipe of similar kind, Fig. 6, we find leakage in the Standard = 1017 gallons; in deep socket = 585 gallons. These joints were Rosendale, 1 to 1. The apparent eccentricity of No. 25 caused the leakage to be greatest in the standard. My opinion is that with joints equally well made the seepage would vary as the thickness of the joint, and inversely as the depth. This would seem to be indicated by the next comparison.

Comparing flush with overfilled joints, Fig. 11, we find a decided gain from overfilling, but there will also be noted a greater eccentricity of results in the overfilled joints.

ROSENDALE CEMENT.

In comparing the different mixtures of Rosendale, it is rather surprising to find that the neat cement makes a poorer record than either a mixture of 1 to 1, or of 1 to 2 with sand; and this is a persistent condition, for, with great irregularity in the record of the tests of the neat cement, every one of them far exceeds in the amount of leakage those of the same kind made with one of cement to one of sand, and the averages for corresponding tests, as shown in Fig. 12, are 139,949 gallons for the neat cement, and 1121 gallons for 1 to 1, or over 100 times as much for the neat cement.

There was one test, No. 11, of 1 to 1, which ran as high as some of the neat tests. This did not correspond in conditions to any of the neat tests, and was not included, and it was the only 1 to 1 test that gave any such results. If this had been included in the average, it would have made it 19,861 gallons, or about one-seventh of the average of neat cement.

Comparing Rosendale 1 to 1 with 1 to 2, Fig. 7, the average leakage of 1 to 1 is 744 gallons, and of 1 to 2, 1207 gallons.

PORTLAND CEMENT.

Fig. 8 shows an average of four similar tests of each for neat cement, of 133 gallons, for 1 to 1, 595 gallons. Comparing joints made of 1 to 1 Rosendale finished with neat Portland ½ inch deep at the outside of the joint, shows, Fig. 9, an average, of two similar tests of each, Portland neat, 68.5 gallons, finish of ½ inch of Portland neat, 237 gallons, which also indicates that the seepage, as already noted, is in inverse ratio to the depth of the joint.

PORTLAND AND ROSENDALE.

Comparing Portland and Rosendale, Fig. 8, shows, for different mixtures, as follows: four similar tests of each, Portland neat, 133 gallons; Portland 1 to 1, 595 gallons; Rosendale 1 to 1, 712 gallons. Compared on a basis of twelve hours set, Fig. 9, two similar tests of each, shows: Portland neat, 68.5 gallons; finish of ½ inch Portland neat, 237 gallons; Portland 1 to 1, 336 gallons; Rosendale 1 to 1, 744 gallons.

TIME OF SETTING.

Comparing the results of 1½ hours set with 12 hours set, Fig. 10 (average of six tests of each) shows 1½ hours set, 578 gallons; 12 hours set, 383 gallons.

The following table gives a comparison of the results of six tests in which the joints were first tested with 12 hours set or less, and afterwards with a longer set.

Table Giving Comparison of Leakage with Increased Time of Setting.

No. of Test.	First Test.		Second Test.		Percentage of	
	Length of Set.	Leakage.	Length of Set.	Leakage.	Reduction.	Increase.
7	12 hours.	102	12 days.	78	13.6	
10	12 "	285,000	36 hours.	191,000	23.	
11	6 "	216,000	16 "	160,300	15.7	
12	12 "	251,500	18 "	272,000		8.5
14	12 "	1,056	43 "	823	12.	
19	12 "	4,820	24 "	4,330	10.	

MORTAR MIXED WET OR DRY.

In this respect the results of the tests are rather contradictory, but they seem to show that the best results are obtained when the mortar is

of such consistency that the largest amount will stay upon a trowel, neither falling apart from dryness, nor running from moisture. This was especially true of Rosendale. In Portland the apparent effect of moisture was less marked.

GROOVED SOCKETS.

Comparing grooved sockets with plain ones, Fig. 13, representing six similar tests of each, shows: grooved, 4,956 gallons; plain, 1,790 gallons.

GASKET.

Two tests were made with untwisted jute gaskets saturated with neat cement grout of the kind of cement used for the joint. The results, compared with similar tests without gaskets, are:

Rosendale 1 to 1, 12 hours set; with gasket, 1,050, without, 950. Portland neat, 12 hours set; with gasket, 323, without 98. The test without gaskets, taken for comparison, gave the highest leakage of any of their class, the average being respectively 744 and 68.5 gallons. The gasket occupies about ¼ of the depth of the joint. These tests also indicate that the seepage is in inverse ratio to the depth of joint.

JOINTS MADE WITH PIPE IN A HORIZONTAL POSITION.

One test was made of joints made with pipe lying in a horizontal position as in the trench. Much trouble was experienced in making these joints, and about as much time was consumed as would have been required to make four or five sets with the pipe in a vertical position, and it was difficult to use the mortar dry enough to prevent it from settling down from the top of the joint. The first joint of the two was made with very dry mortar, but it was necessary to go over it three times before it set enough to remain in place. The other joint was made of mortar so dry that it had the appearance of moist sand with no cohesion unless compressed. This was rammed into place with a wooden rammer, and both joints were finally successful, with a leakage of 118 gallons, as compared with 98 gallons, the greatest leakage in neat Portland joints made in a vertical position. These joints were deep socket, and it is probable that wetter mortar could have been used in the standard without sloughing down, but I doubt if so good a joint could have been made in the standard in that position.

ASPHALT PAINTED JOINT.

Rather from curiosity than from any idea of utility, I treated some joints, after testing, by painting them with asphalt cut with turpentine. known as Warren's Asphalt Varnish, T brand. The joints were painted

on the outside with three coats, one after the other, as they soaked in and dried. They were then tested again, and the result is shown in the following table:

Table Giving Leakage of Ten Tests Before and After Being Painted with Asphalt Varnish.

No. of Tests.	Leakage per Mile in Twenty-four Hours.		
	Before Painting.	After Painting.	Per cent. of Reduction.
7 A	85 gallons.	0 gallons.	100. per cent.
11 A	160,300 "	8,350 "	94.8 "
18	285 "	0 "	100. "
25	3,605 "	105 "	97. "
26	7,240 "	713 "	90. "
27	437 "	82 "	71.2 "
28	1,648 "	1,060 "	35.6 "
30	2,370 "	740 "	68.8 "
35	616 "	0 "	100. "
45	368 "	41 "	88.9 "

An examination of the tests and a comparison of the averages would seem to lead to the following conclusions:

In the "Standard" form of pipe socket, with well made joints of either Portland cement neat or 1 to 1 of sand, or of Rosendale cement 1 to 1 of sand, with overfilled joints, the leakage would not be serious, probably not to exceed 1,000 gallons per mile per day, with the level of the ground water from 2 to 8 feet over the pipe.

But the smallness of the room for cement in this joint makes it exceedingly difficult to make a full joint in the trench, and, although the tests show a fairly good result, I think it is impossible to approximate to such results in actual practice in a wet trench, and for this reason it would seem wiser to use a larger and deeper socket where tight work is desirable.

In pipe with "deep sockets" the tests indicate that if the joints are well made the leakage would be about as follows: In Rosendale cement neat it would be very large, perhaps over 100,000 gallons per mile per day. In Rosendale cement mixed with sand in the proportion of 1 to 1, the leakage would not exceed 700 to 800 gallons per mile per day. In Rosendale mixed with one part of cement to two parts of sand, it would approximate 1,000 or 1,200 gallons per day. With Portland cement neat, about 150 gallons per day; with Portland 1 to 1, about 500 or 600 gallons.

With the wider and deeper sockets the mortar can be more easily

put into the joint, and a wooden rammer of sufficient thickness to be effective in compacting the mortar, can be used. The greater depth of the joint apparently reduces the seepage and renders it more likely that imperfectly filled portions of the joints will be covered by better compacted portions. It also gives a greater body of cement to resist the action of the water reaching it before it is set; and it allows the mortar to be placed within the joint instead of outside of it. Mortar applied outside of the joints is of doubtful value in a trench where water is liable to reach it before it is set. The increased length of the joint aids very materially in preventing the pipe from moving in the joint and from thus making a direct passage for the water into it. It of course requires more mortar directly in the joint, but it is doubtful if the waste of mortar is as great as in the narrow sockets. The amount of mortar required to make the different joints, and the approximate cost of the same per joint, are given in Tables II, III, IV and V.

A gasket apparently increases the leakage by reducing the length of the joint, and thus reducing also the resistance to the passage of water; but in a very bad trench, where the water is likely to blow or wash the cement from the joint, it would prevent the sand from entering the pipe, and, if thoroughly saturated in a grout of neat cement, might aid in preventing the passage of water.

If water under pressure could be kept from the pipe for twelve hours the seepage, especially in the Rosendale cement, would be materially reduced.

It would seem to follow from the foregoing that Rosendale or Portland cement, either neat or mixed with sand in the proportion of 1 to 1, or 1 to 2, would make work that was sufficiently tight for all practical purposes, if the joints could be well filled and could remain undisturbed by water or otherwise until sufficiently set to resist it; but the great advantage of the Portland cement is that it will set in one and a half or two hours as firmly as the Rosendale will in twelve hours. That is about the proportion with the brands which were used in these tests.

The great trouble is to make good joints, and this is largely due, I think, to the shortness of the pipe. This would dictate the use of three-foot instead of two-foot lengths of pipe, which would reduce the number of joints 33 per cent.; then if two joints of the pipe could be put together on the bank and allowed to set twelve or twenty-four hours before laying, it would again reduce by 50 per cent. the number of joints to be made in the trench, and thus reduce also the liability of poor joints, for I am satisfied that a well-made joint, undisturbed until set, is *good enough.* But the difficulty in making joints on the bank is in the alignment of the pipe. The ends are not square and true, and they cannot be depended upon to give the proper alignment. It would be interest-

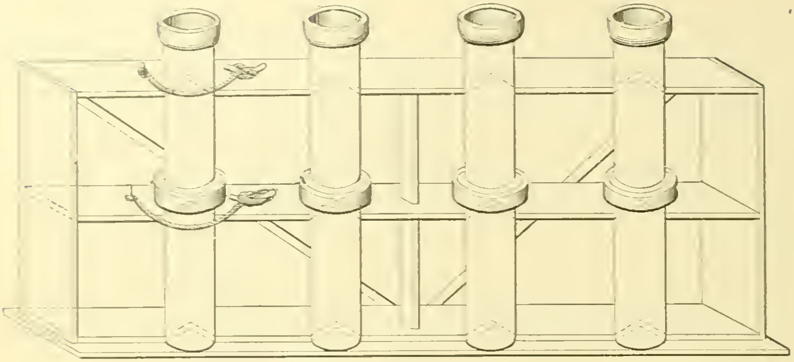


FIG. 14.

ing to experiment with a set of cradles of boards and plank, Fig. 14. Thus arranged, the pipes could be given perfect alignment, and the joints could be made in advance of the work of trenching. If neat Portland were used, they could be removed after one and a half hours; and if of Rosendale they could be removed in four or five hours, and stood on end ready to be laid. It would be well to be twenty-four hours or more in advance of the laying. The joints could in this way be made nearly perfect, and in about one-fourth to one-sixth the time required in the trench, with less waste of cement. We should then have six-foot lengths to lay, a sufficient bell-hole and pump-hole could be dug, and a dam could be made across the pipe to hold back the water while a comparatively good joint could be made in the trench. It would be an experiment, of course, but I believe it would be a successful one, and the pipe could be laid better, and even cheaper, than by making each joint in the trench. The expense would not exceed $25 or $30 for enough cradles to prepare pipe for laying 500 feet per day. One set of cradles would take pipe from four inch to twelve inch, and another set the larger sizes.

In these tests no attempt was made to test different brands of cement. The cement that was used seemed to be of good quality, but was not tested in any way except in the joints and by a sieve. The sieve was 6,400 meshes to the inch, and retained 14 per cent. of the Portland and 28 per cent. of the Rosendale.

I am well aware that the results of these tests are only relative and not a positive indication of what would occur in the actual trench. For instance, the material in which the pipe was laid would largely affect the leakage into it, and other tests, made under conditions similar to those which here obtained, might give entirely different results. This paper claims only to be a record of what actually took place under the given conditions. The tests were made with considerable care, and the

results are recorded truthfully and without bias. Others might interpret the results otherwise, but the opinions formed by the writer are the result of a study of the tests after their completion, and of the impressions left upon his mind by the actual handling of the material. They are offered in the hope that they may help a little toward overcoming, in part at least, the infiltration of ground water. No tests were made of any other material than cement, as there seems to be, at present, nothing that promises to take its place. The tables given are computed from careful measurements, and they may aid in estimating the cost of sewer construction. The tables of cost will give a ready means of comparison of the cost of different mixtures of cement and of different forms of joints for a system of sewers.

TABLE I.

Consecutive Record of Sewer-Joint Experiments.

No.	Form of Socket.	Form of Joint.	Kind of Cement.	Mixture of Cement and Sand.	Time of Setting.	Duration of Test.	Amount of Leakage.	Leakage per Mile per 24 Hours, with Joints 2 Feet Apart. Cubic Feet.	Leakage per Mile per 24 Hours, with Joints 2 Feet Apart. U. S. Gallons.	Remarks.
1	Standard	Flush	Rosendale	1 to 1	12 hours	3 hours	8.83	54.	404	
2	"	"	"	Neat	12 "	3 minutes	45.6	17080.	127,800	Very minute cracks.
3	"	"	"	"	12 "	15 "	520.	38150.	285,000	
4	"	Overfilled	"	"	12 "	3 hours	12.4	75.8	567	
5	"	"	"	"	12 "	20 minutes	782.	43300.	324,000	Minute cracks.
6	"	"	"	1 to 1	12 "	11 hours	12.6	21.	157	
7	"	"	"	"	12 "	8.5 "	6.21	13.4	102	Mortar very dry.
7 *A*	"	"	"	"	12 days	12 "	6.78	10.4	78	No. 7 repeated.
8	Deep socket	Flush	"	"	12 hours	9.5 "	37.2	71.9	538	
9	"	"	"	"	12 "	7 "	48.5	127.	950	
10	"	"	"	Neat	12 "	15 minutes	520.	38150.	285,000	Minute cracks.
10 *A*	"	"	"	"	36 "	23 "	520.	25570.	191,000	Remained in water, without pressure, 24 hours.
11	"	"	"	1 to 1	6 "	20 "	520.	28900.	216,000	
11 *A*	"	"	"	"	16 "	40 "	780.	21450.	160,300	No. 11 repeated.
12	"	"	"	Neat	12 "	17 "	520.	33650.	251,500	
12 *A*	"	"	"	"	18 "	7 "	231.	36400.	272,000	No. 12 repeated.
13	"	"	"	1 to 1	6 "	5 hours	13.8	46.9	351	
14	"	"	"	"	12 "	7 "	54.	141.5	1,056	Jute gasket, saturated with neat Rosendale.
14 *A*	"	"	"	"	43 "	11.5 "	69.2	110.	823	
15	. . . . . .	. . . . . .	. . . . . .	. . .	. . . .	. . . . . .	.	. . . .	. . . .	Made with poor cement; not tested.
16	Deep socket	Overfilled	Rosendale	1 to 1	12 hours	7.66 hours	14.7	35.2	263	
17	"	"	"	"	12 "	11.25 "	48.4	79.	591	
18	"	"	"	Neat	12 "	6 "	12.5	38.2	285	
19	"	"	"	"	12 "	2.83 "	101.5	658.	4,820	
19 *A*	"	"	"	"	24 "	.5 "	15.9	578.	4,330	
20	"	Flush	"	1 to 1	12 "	1.5 "	5.4	65.	486	Grooved socket.
21	"	"	"	"	3 "	1.33 "	8 32	114.7	859	
22	"	"	"	"	$1\frac{1}{2}$ "	.83 "	5.62	124.	925	Mortar very dry.
23	"	"	"	"	6 "	.58 "	10.05	317.5	2,374	Mortar rather wet.

24	Deep socket	Flush	Rosendale	1 to 1	36 hours	10	hours	31.9	58.4	436	Grooved socket.
25	Standard	"	"	"	12 "	5	"	131.3	482.	3 605	
26	Deep socket	"	"	"	12 "	.5	"	26.4	968.	7,240	Grooved socket.
27	"	"	"	"	1½ "	8.25	"	25.9	58.5	437	
28	"	"	"	1 to 2	12 "	11.5	"	138.3	220.5	1,648	
29	"	. . . .	. . . .	. . .	. . . .	. . . . .		. . .	. . . .	. . . .	Moved in joint; made no test.
30	"	Overfilled	Rosendale	1 to 1	10 days	2	hours	34.6	317.	2,370	From poor lot of cement.
31	"	Flush	"	1 to 2	12 hours	2.16	"	12.1	102.6	766	
32	"	"	"	Neat	3 "	1	"	45.8	841.	6,290	
33	"	"	"	"	3 "	.42	"	46.6	2015.	15,080	Grooved socket.
34	"	"	"	1 to 1	3 "	1	"	28.	514.	3,840	Suspect this moved.
35	"	"	"	"	3 "	5	"	22.5	82.5	616	
36	"	"	"	"	16 days	19	minutes	231.	13380.	100,000	No. 11 and 11 *A* repeated.
37	"	"	"	"	24 hours	11	hours	28.	46.6	348	
38	"	"	"	"	. . . .	8.5	"	5.1	11.	82	No. 27 painted asphalt.
39	"	"	"	"	24 hours	3	"	33.6	205.5	1,538	Grooved socket.
40	"	"	"	"	. . .	2	"	10.4	95.4	713	No. 26 repeated asphalt.
41	"	"	Portland	"	12 hours	2	"	4.5	41.3	304	
42	"	"	"	"	1½ "	1.58	"	8.8	102.3	765	
43	"	"	"	Neat	1½ "	1	"	.43	7.9	59	
44	"	"	"	"	1½ "	1.75	"	4.32	45.2	337	
45	"	"	"	1 to 1	12 "	8	"	21.5	49.3	368	
46	"	"	Rosendale	1 to 2	. . . .	4.75	"	36.7	141.7	1,060	No. 28 painted asphalt.
47	"	Overfilled	" (poor)	1 to 1	. . . .	8	"	43.2	99.	740	No. 30 painted asphalt.
48	Standard	"	"	"	. . . .	12	"	0.0	0.	. . . .	No. 7 painted asphalt.
49	"	Flush	"	"	. . . .	9	"	6.91	14.1	105	No. 25 painted asphalt.
50	Deep socket	"	Portland	"	1½ hours	2	"	13.8	126.3	945	
51	"	"	Rosendale	"	. . . .	9	"	0.	0.	. . . .	No. 35 painted asphalt.
52	"	"	"	"	12 hours	2.5	"	4.32	31.65	236	½ neat Portland on top.
53	"	"	Portland	Neat	12 "	7.5	"	2.16	5.17	39	
54	"	Overfilled	Rosendale	"	. . . .	12	"	0.	0.	. . . .	No. 18 painted asphalt.
55	"	Flush	"	1 to 1	. . . .	1.33	"	81.1	1116.	8,350	No. 11 painted asphalt.
56	"	"	Portland	Neat	12 hours	12	"	8.65	13.2	98	Mixed wet.
57	"	"	"	1 to 1	. . . .	5.75	"	1.73	5.5	41	No. 45 painted asphalt.
58	"	"	Rosendale	"	12 hours	12	"	20.9	31.9	238	½ neat Portland on top.
59	"	"	Portland	Neat	1½ "	6	"	5.18	15.8	118	Made lying on its side.
60	"	"	"	"	12 "	7½	"	17.7	43.2	323	Gasket saturated with cement.
61	Standard	Overfilled	"	"	12 "	12	"	5.83	8.9	67	Made very wet.
62	Deep socket	Flush	Rosendale	1 to 1	12 "	.25	"	19.	1392.	10,410	Made very dry.
63	"	"	"	"	12 "	10½	"	59.6	104.	776	Made very wet.

TABLE II.

Quantity and cost of cement per joint in deep sockets with flush joints (Fig. 4).

Diameter of Pipe.	Contents in Cubic Feet.	Portland Cement.		Rosendale Cement.	
		Neat.	1 to 1.	Neat.	1 to 1.
4 inch . .	.0191	$.014	$.008	$.008	$.0046
5 " . .	.0234	.017	.010	.010	.0056
6 " . .	.0267	.020	.011	.011	.0064
8 " . .	.0332	.024	.014	.014	.0080
10 " . .	.0406	.030	.017	.017	.0098
12 " . .	.0478	.036	.020	.020	.0115
15 " . .	.0708	.052	.029	.029	.0171
18 " .	.0845	.062	.035	.035	.0203
20 " . .	.0937	.069	.038	.038	.0226
24 " . .	.1452	.107	.060	.060	.0350

TABLE III.

Quantity and cost of cement per joint in deep sockets with overfilled joints (Fig. 5).

Diameter of Pipe.	Contents in Cubic Feet.	Portland Cement.		Rosendale Cement.	
		Neat.	1 to 1.	Neat.	1 to 1.
4-inch . .	.0346	$.0254	$.0143	$.0143	$.0083
5 " . .	.0400	.0294	.0165	.0165	.0096
6 " . .	.0557	.0410	.0230	.0230	.0134
8 " . .	.0762	.0560	.0314	.0314	.0184
10 " . .	.0926	.0680	.0382	0382	.0226
12 " . .	.1093	.0805	.0451	.0451	.0264
15 " . .	.1603	.1175	.0562	.0562	.0386
18 " . .	.1905	.1400	.0787	.0787	.0460
20 " . .	.2407	.1770	.0993	.0993	.0580
24 " . .	.3312	.2430	.1365	.1365	.0800

TABLE IV.

Quantity and cost of cement per joint in standard sockets with flush joints (Fig. 2).

Diameter of Pipe.	Contents in Cubic Feet.	Portland Cement.		Rosendale Cement.	
		Neat.	1 to 1.	Neat.	1 to 1.
4-inch . .	.0045	$.0033	$.0018	$.0018	$.0011
5 " . .	.0054	.0040	.0022	.0022	.0013
6 " . .	.0065	.0047	.0027	.0027	.0015
8 " . .	.0080	.0058	.0033	.0033	.0019
10 " . .	.0100	.0073	.0041	.0041	.0024
12 " . .	.0140	.0102	.0057	.0057	.0034
15 " . .	.0220	.0160	.0090	.0090	.0053
18 " . .	.0270	.0197	.0110	.0110	.0065
20 " . .	.0300	.0219	.0123	.0123	.0072
24 " .	.0350	.0256	.0143	.0143	.0084

TABLE V.

Quantity and cost of cement per joint in standard sockets with overfilled joints (Fig. 3).

Diameter of Pipe.	Contents in Cubic Feet.	Portland Cement.		Rosendale Cement.	
		Neat.	1 to 1.	Neat.	1 to 1.
4-inch . .	.0013	$.0082	$.0046	$.0046	$.00272
5 " . .	.0134	.0098	.0054	.0054	.00323
6 " . .	.0195	.0143	.0080	.0080	.0047
8 " . .	.0315	.0229	.0129	.0129	.00759
10 " . .	.0393	.0286	.0161	.0161	.00947
12 " . .	.0479	.0349	.0196	.0196	.0115
15 " . .	.0640	.0467	.0262	.0262	.0154
18 " . .	.0877	.0640	.0358	.0358	.0211
20 " . .	.1443	.1053	.0591	.0591	.0347
24 " . .	.1700	.1241	.0697	.0697	.0410

TABLE VI.

Table giving cost per cubic yard of different mixtures of mortar.

Portland cement taken at $2.50 and Rosendale at $1.25 per barrel; sand a $1.50 per cubic yard.

Kind of Mixture.	Portland Cement.				Rosendale Cement.			
	Cement.	Sand.	Labor.	Total Cost.	Cement.	Sand.	Labor.	Total Cost.
Neat.	$19 30	$ 0	$0 50	$19 80	$10 55	$0 00	$0 50	$11 05
1 to 1	9 70	92	0 50	11 12	5 12	91	0 50	6 53
1 to 2	6 28	1 19	0 50	7 97	3 24	1 17	0 50	4 91
1 to 3	4 63	1 31	0 50	6 44	2 36	1 26	0 50	4 12
1 to 4	3 63	1 37	0 50	5 50	1 88	1 34	0 50	3 72

THE CONTRIBUTION BOX.

Members of the associated societies, and other persons, are invited to send to the Secretary, for this department of the JOURNAL, such matters of general interest as may come to their notice.

The Action of the Western Society of Engineers.

It is with profound satisfaction that the Box records the result of the letter ballot by the Western Society of Engineers, continuing, by the handsome vote of 137 to 70, the co-operation of that society in the work of the Association.

It is needless to say that the loss of that co-operation would have been a serious one, not only by reason of our deprivation of the literary and financial support of that very important society, but also through the moral effect of the statement that one of our largest societies had found the advantages of the JOURNAL insufficient to prevent it from embarking in the doubtful experiment of issuing its own papers, confining their circulation chiefly to its own membership, and depriving that membership of the papers of the other societies.

It is, therefore, particularly gratifying that the society has expressed itself so unmistakably in its endorsement of the value of the Association and of its JOURNAL.

The Journal.

It has recently come to the notice of the Box that, through oversight on the part of the binders, a number of the copies of the JOURNAL for June were sent out without the insertion of the four plates which should have accompanied them. Fortunately, the impressions were still upon the stone, and a number of copies have been made from them. The Secretary will be glad to furnish these to any readers of the JOURNAL who may require them to make this number complete.

The Secretary is prepared to furnish a few sets of back numbers of the JOURNAL, Vols. I to XII, to December, 1893, inclusive, lacking ten numbers, as follows:

Vol. I, No. 1, Nov. 1881.	Vol. VII, No. 3, Mar. 1888.
" I, " 2, Dec. "	" VII, " 5, May, "
" I, " 3, Jan. 1882.	" VII, " 6, June, "
" I, " 4, Feb. "	" VII, " 7, July, "
" I, " 5, Mar. "	" VII, " 8, Aug. "

The price is $30 per set, but they are for the present offered *to members of the Associated Societies* at $25 each. Those having spare copies of any of the ten missing numbers are requested to communicate with the Secretary, at 419 Locust Street, Philadelphia.

Dinner to President Craighill, of the A. S. C. E.

On Monday evening, December 10th, the members of the American Society of Civil Engineers resident in and near Philadelphia emulated the example of their brethren in Washington and other cities by tendering a complimentary dinner to Col. Wm. P. Craighill, President of the American Society of Civil Engineers.

The dinner was given at the Hotel Stenton, and was attended by about fifty gentlemen, including a number of prominent members of the society from New York, Washington and other cities.

THE LIBRARY.

It is proposed to notice briefly in this department of the JOURNAL such engineering publications as may find their way to our shelves.

Publishers are requested, in sending works for review, to state the prices of same.

Public Works. A Treatise on Subjects of Interest to Municipal Officers. By Ernest McCullough, Member of the Technical Society of the Pacific Coast. 1894. Pamphlet, 54 pages.

This little work, prepared for the information of the trustees of a California town, is now published chiefly for the benefit of other corporations of the same kind. It embraces the various subjects coming within the range of municipal engineering, and the various chapters may be said to constitute condensed specifications of what should be sought and what should be avoided in such constructions.

India. WAYS AND WORKS IN ——. By G. W. MacGeorge, Member, Instn. Civ. Engrs. 565 pages; 6 x 9, with index and 5 colored maps. Price, 5 shillings. Westminster: Archibald, Constable & Co. 1894.

The author disclaims any intention of laying before his readers a precise and detailed history of Indian public works, however valuable such a history might be, and confines himself rather to a popular account of some of the more important features, gathering his materials chiefly from official publications, government records and the *Proceedings of the Institution of Civil Engineers.*

The great Indian Trigonometrical Survey is treated at considerable length, and with an introduction calculated to familiarize the unitiated reader with the methods of trigonometrical surveying in general.

Naturally, the subject of irrigation works comes in for extensive mention, over two hundred pages being devoted to this subject alone.

The chapters on railways in India contain much matter of historical and technical interest, including accounts of some of the notable railway bridges of that country. Photographic views of the Jumna bridges at Allahabad and at Delhi, and of the Jubilee bridge over the Hooghly, near Calcutta, are given, as well as one of a small bridge over the deep and rocky Chupar Rift, on the Hurnai Valley Railway. Other chapters treat of water supply, electric telegraph, roads, and sea and harbor works.

Among the appendices, is one on the subject of color-blindness, the connection of which with the subjects mentioned on the title-page seems to be rather remote.

Society Proceedings.

UNITED STATES ARTILLERY. Journal of the ——. Published by authority of the staff of the Artillery School, July, 1894. Volume III, No. 3, whole number 12. Artillery Press: Fort Monroe, Va.

If the vast amount of mental energy now being expended upon the perfection of the arts of war should ever assume the kinetic form in civilized countries, it would be a serious day for the race. The author of a series of letters on Sea-Coast Artillery, with which this number begins, quotes Admiral Aube as saying that our

time is an epoch of transformation, of passage from an ancient order, which is slow to die, to a newer one, which is slow to assert itself. The applicability of this to the substitution of modern and scientific methods of settling international questions in place of the ludicrously clumsy methods of warfare, is so apparent that it seems strange that the author should apply the thought solely to improvements in the detail of the latter methods.

Lieut. E. M. Weaver contributes a third paper, of 41 pages, to his Notes on Armor, accompanying them with numerous tables and diagrams; and Lieut. Joseph E. Kuhn translates a paper by Heinrich Edler von Brilli, of the Austrian Artillery, on a New Method of Indirect Laying for Field Artillery.

It is much to be wished that the members of our societies would enable the Secretary of the Association to present something analagous to the 42 pages of professional notes which are presented in this number, and which are followed by 17 pages of book notices, and by a department of scientific and military information to which 25 pages are devoted.

American Society of Civil Engineers. Transactions of the ——.
October, 1894. Vol. XXXII, No. 4.

Mr. Frederick H. Lewis, member of the Engineers' Club of Philadelphia, and Mr. J. Edward Whitfield, contribute Some Notes on Hot-Bath Tests for Cements, the results of experiments extending over rather more than a year, with temperatures generally at 180° Fahrenheit, as recommended by Mr. Maclay. The remarks bear chiefly upon the effect of free lime, the authors believing that if the lime is pulverized it will usually become sufficiently slaked before mixing, and will thus cause little or no trouble. The paper is discussed at considerable length by Mr. Robert W. Lesley, Mr. W. W. Maclay, and others.

Mr. William Lee Sisson, in an illustrated paper, describes the improvements in the Baltimore and Ohio Railroad, in the neighborhood of Harper's Ferry, involving the construction of a new bridge across the Potomac, the driving of a tunnel 812 feet long, and 50,000 yards of rock cutting, in depths reaching to 80 feet.

Mr. O. F. Nichols, in a paper referred to in the Contribution Box for November, describes the Myrtle Avenue improvement on the Brooklyn Elevated Railroad.

November, 1894. Vol. XXXII, No. 5.

This number contains a paper by Mr. E. Sherman Gould, on the Dunning's Dam, near Scranton, Pa., and one by Mr. John P. O'Donnell on the Block System of Railroad Signaling. The Dunning's Dam is fifty feet high above the level of the water in the brook and 153 feet long on the spillway. The masonry portion has a back vertical or nearly so, and the front, which is stepped, inclines at an angle of about 45 degrees. This portion rests upon a concrete foundation, and has in front of it an apron about sixty feet wide, composed of two courses of masonry with a 12-inch layer of concrete between them. In front of this is a timber crib filled with stones. The masonry dam is backed with earth, which extends, in its widest part, about 450 feet back from the masonry. The structure may thus be regarded as an earthen dam with masonry spillway.

Mr. O'Donnell's paper was one of those read at the annual convention at Niagara Falls in June last. It may be said to be a review of the entire subject in the historical and in the technical sense. It is based largely upon English practice.

Association
of
Engineering Societies.

PROCEEDINGS.

Annual Report of the Chairman of the Board of Managers.

Chicago, February 6, 1894.*

To the Board of Managers of the Association of Engineering Societies:

Gentlemen:—I respectfully submit herewith the statement of the affairs of the Association for the year 1893.

In Appendix 1 is a condensed statement of the receipts and expenditures by months, and, in Appendix 2, an itemized statement of the cost of publication.

It is seen that the total expenses for two thousand (2,000) copies of the Journal for twelve months, including the Secretary's salary and the cost of preparing the index, was $4,517 78
and the receipts, including the balance from 1892, were 4,345 41

leaving a balance due the Secretary of $172 37
To which should be added, for miscellaneous expenses of the retiring Chairman 9 50

Total balance due $181 87

The average total membership of the Associated Societies was about 1,230, and the cost per member per annum $3.16.

The increase in cost for 1893 over 1892 is readily accounted for by the increase of fully 50 per cent. in the size of the Journal.

This increase was foreshadowed in my last annual report.

On the 1st of August the Board of Managers held a meeting in Chicago, the proceedings of which were published in the July issue of the Journal, at which the resignation of your Chairman was accepted, to take effect January 1, 1894. Rules were adopted governing the election and term of office of the Secretary and

*Owing to the fact that the transfer of the publication office to Philadelphia was not fully decided upon by the Board of Managers until January 30th, so that the first of the copy for the present (January) number did not reach the publication office until February 8th, the issue of that number has been so long delayed that it is possible to insert in it the report of the retiring Chairman, Mr. Benezette Williams, although that document is dated February 6th The report is so inserted, at the request of Chairman J. B. Johnson, notwithstanding the anachronism involved.

The Secretary.

Chairman. In accordance with these rules, an election was held by letter ballot, which, on being counted November 1st, resulted in the election of Prof. J. B. Johnson as Chairman, and Mr. John C. Trautwine, Jr., as Secretary. With this report, my last official duty as Chairman will come to an end.

The late Secretary, Mr. John W. Weston, has, at this writing, turned over the work of his office to Mr. Trautwine, and he will soon transmit to him all back numbers of the JOURNAL and other property of the Association.

With December, 1893, the JOURNAL completes its twelfth volume. The first number was issued under date of November, 1881. The total membership of the Associated Societies was at that time about 400. It is now about 1,200.

The expenses of the Association have never been less than $2.50 per member per annum, and they have averaged about $3 00.

The smallest amount of matter published in any one year was 329 pages, in 1884; and the largest, 657 pages of text and 107 pages of index in 1893.

The average size of a volume of the JOURNAL has been 491 pages of text, and, for the last nine years, about 64 pages of index. The index is printed twice; first in the current monthly issue, and a second time in the annual summary.

The memberships of the several associated societies on January 1, 1894, as shown by the Secretary's mailing list, were as follows:

Western Society of Engineers	354
Boston Society of Civil Engineers	325
Engineers' Club of St. Louis	159
Civil Engineers' Club of Cleveland	184
Engineers' Club of Kansas City	21
Montana Society of Civil Engineers	40
Civil Engineers' Society of St. Paul	28
Engineers' Club of Minneapolis	31
Wisconsin Polytechnic Society	42
Total	1,184

That the work accomplished by the Association during the more than twelve years of its existence has been creditable to itself, and on the whole beneficial to the engineering profession, will, no doubt, be readily granted; but that it has failed in some of the broader lines which the hopes of its more ardent friends had marked out for it, must also be granted.

The reasons why at least two of the stronger local societies of the country hold aloof from the Association have never been made fully apparent.

In submitting this, his last annual report, your retiring Chairman can only express the hope that the objections heretofore urged by those societies may be overcome; that all which are now members of the Association may so remain; and that the Association may bring about that harmony and unity of our local engineering interests which is so greatly needed by the profession in this country. He would also thank the members of the Board of Managers for their unfailing kindness and forbearance, and for their faithful co-operation in the work of the Association.

Respectfully submitted,

BENEZETTE WILLIAMS, *Chairman.*

APPENDIX 1.

Statement of Receipts and Expenditures during 1893.

Receipts.

By Months.		By Sources.	
Balance from 1892	$72 86	Balance from 1892	$72 86
January	196 52	From assessments	3,636 45
February	413 52	" advertisements	103 00
March	140 60	" subscribers	533 10
April	523 15		
May	439 70		
June	64 00		
July	541 50		
August	398 60		
September	34 65		
October	683 81		
November	82 10		
December	754 40		
	$4,345 41		$4,345 41

Expenditures.

	Cost of Publication.	Office expenses, including Postage and Mailing.	Total.
January	$289 34	$23 01	$312 35
February	244 88	21 02	265 90
March	242 46	27 79	270 25
April	266 45	20 33	286 78
May	195 25	20 00	215 25
June	214 03	24 31	238 34
July	246 55	32 66	279 21
August	225 38	15 64	241 02
September	201 65	16 03	217 68
October	267 96	15 45	283 41
November	301 91	22 13	324 04
December	752 14	56 41	808 55
	$3,448 00	$294 78	$3,742 78
Secretary's salary			600 00
Index notes			175 00
			$4,517 78

APPENDIX 2.

Items of Cost of Publication of Journal, Vol. XII, 1893.

	Ems.	Composition, Printing, Binding and Mailing.	Paper.	Time.	Illustrations.
January	177,491	$53 20	$54 70	$13 00	$61 95
February	225,060	40 70	55 95	9 50	3 70
March	155,662	34 70	51 02	8 50	54 85

	Composition, Ems.	Printing, Binding and Mailing.	Paper.	Time.	Illustrations.
April	$170,842	$45 10	$56 70	$9 50	$52 65
May	172,582	30 90	46 20	9 00	5 60
June	168,973	37 70	52 25	14 00	8 70
July	151,481	40 50	57 15	15 00	43 02
August	147,200	40 00	55 92	11 50	29 64
September	153,000	39 00	50 35	12 00	8 50
October	192,437	41 00	64 50	13 00	34 00
November	262,000	51 50	79 20	14 00	. . .
December	742,325	102 00	140 45	18 00	46 30
	2,719,053	$556 30	$764 39	$147 00	$348 91

Summary.

Composition, 2,719,053 ems, at 60 cents per 1,000 ems	$1,631 40
Printing, binding and mailing	556 30
Paper	764 39
Time work	147 00
Illustrations	348 91
Total	$3,448 00

Boston Society of Civil Engineers.

December 30, 1893.—A regular meeting of the Society was held at its rooms, 36 Bromfield Street, Boston, at 7.35 o'clock, p.m. President Freeman in the chair. Sixty-five members and forty-six visitors present.

The record of the last meeting was read and approved.

Messrs. John C. Chase, of Wilmington, N. C., and Robert S. Hale, of Boston, were elected members of the Society.

A memoir of the late Richard Fobes, of Worcester, a member of the Society, was presented by Messrs. L. A. Taylor and C. A. Allen, a committee of the Society.

Mr. Henry Manley exhibited specimens of the Teredo Navalis, found in the planking of a scow that had been at work in Boston Harbor during the past summer, and gave a short account of the habits of this animal. A discussion followed, in which Messrs. Tidd, Frizell, Swain and others took part.

Mr. Arthur W. Hunking read the second part of the paper presented by him at the last meeting, entitled "Notes on Water Power Equipment and Considerations Affecting the Selection of a Turbine." In the discussion which followed, Messrs. Frizell, Hale and Freeman took part.

The discussion of the evening, on the Organization of a City Engineer's Office, was then taken up, and, in the absence of the author, the Secretary read a paper prepared by Mr. Albert F. Noyes. The discussion was continued by Messrs. Kimball, McClintock, Swan and others.

Adjourned. S. E. Tinkham, *Secretary.*

Western Society of Engineers.

310TH (ANNUAL) MEETING, JANUARY 3, 1894.—The Annual Meeting of the Society was held at the Sherman House, at 6 P.M., January 3, 1894, with President Robert W. Hunt in the chair and 63 members and guests present.

The reading of the minutes of the previous meeting was dispensed with.

President Hunt reported the following action of the Board of Directors at its meeting of December 20th: Messrs. Virgil G. Bogue, James H. Brace, Henry Goldmark and Alfred Noble were elected to membership. The applications for membership of Messrs. Wallace C. Evans and Almon D. Thompson were received and placed on file.

The following members were appointed Tellers to act in counting the votes at the Annual Meeting: Messrs. Hosea Webster, C. T. Purdy and L. C. B. Holmboe.

The resignations of the following members were accepted: Messrs. S. S. Greeley, A. L. Hammarberg, S. F. Balcom, C. McLennan, H. E. Hilgard and Frank S. Baillie.

The resignation of Mr. L. P. Morehouse from the Board of Managers of the Association of Engineering Societies was received.

At the meeting of the Board of Directors held January 2, 1894, the Secretary was directed to enter on the minutes of the Board of Directors the names of members dropped from the membership list on account of failure to pay dues under the provisions of the By-Laws relating to delinquents.

The Secretary then read his annual report for the year 1893, as follows:

REPORT OF SECRETARY.

The Society has held ten regular and two special meetings during the year. The average attendance, apart from that at the dinner to Mr. James Dredge, in May, and that at the Annual Meeting in January last, has been 30 members and guests. At the Annual Meeting in January last there was a gathering of some 130 persons, while at the Dredge banquet 100 persons were present.

The membership of the Society to-day amounts to 354 members. The falling off is accounted for by the fact that the Board of Directors at its last meeting, under the mandatory provisions of the By-Laws, dropped from the rolls 96 names—52 delinquent for 1893, and 44 for delinquencies in 1893 and previous years.

We have also to record six resignations which have been accepted, and the addition of 30 names to the list during the year.

I regret to record that we have lost from our membership by death during the past year, Joseph A. Watson, Wm. Scherzer and B. B. Colborne.

The following papers have been presented during the past year:

Comparative Tests of Two Smoke Consuming Devices for Steam Boiler Furnaces. By J. C. McMynn.

A Reduction Formula for Stadia Leveling. By J. L. Van Ornum.

The Relation of Railway Signaling to Train Accidents. By W. W. Salmon.

The Hydro-Geology of the Upper Mississippi and Western Lake Michigan Valley. By Danl. W. Mead.

The Chicago Railway Problem—Discussion. By Thomas Appleton.

Modern Gun Making. By Capt. W. H. Jaques, at Special Meeting in October.

Irrigation—Some Practical Notes on the Engineering and Practical Features of the Question. By A. M. Van Auken.

The Reconstruction of the Burlington Bridge. By George S. Morrison.

The dinner to Mr. Dredge was the notable feature of our May Meeting, and the Special Meeting in October at Van Buren Street was largely attended.

The Secretary has received in all from fees and dues during the year $3,153.64. In addition, the Board loaned to the Society $400—making a total of $3,553.64, and vouchers have been paid to the amount of $3,245.40—leaving a balance of $308.24.

John W. Weston, *Secretary.*

January 3, 1894.

On motion, duly seconded, the report was adopted.

President Hunt:—"Gentlemen, in explanation of the dropping of so many names from the rolls, permit me to call your attention to the provision of your laws. As a matter of fact, these names were erased, not by the Board, but by your own laws. The Board merely saw that the state of the case was as it appeared to be on the Secretary's account." (Mr. Hunt here read sections 7 and 8 of Article VI of the By-Laws.)

"Hence we did not feel at liberty to present to you a list of those names, but restricted ourselves to stating their number. Of course every member will appreciate that all that is necessary for those gentlemen to do is to square up their accounts, and the incoming Board will be only too glad to re-establish their membership. I am sorry to find that the list is so great."

The report of the Treasurer for the year 1893 was read, but, as the Auditing Committee was not ready to report, no action was taken upon it. (This report, together with the report of the Auditing Committee, will appear in the report of the proceedings of the February meeting.)

The Secretary then read the report of the Tellers of the election and the President officially declared the following officers elected: Hiero B. Herr, President; Daniel W. Mead, First Vice-President; H. C. Draper, Second Vice-President; Thomas Appleton, Secretary and Librarian; David L. Barnes, Treasurer; Robert W. Hunt, Trustee.

On motion, duly seconded, the business meeting was then adjourned, and the members and guests repaired to the banquet room, where, after due time spent in discussing the menu and enjoying the music of the mandolin orchestra, the Society was again called to order by President Hunt, who officiated as toast-master in the absence of Mr. Willard A. Smith, detained by sickness. Addresses were made by the retiring President, Capt. Robert W. Hunt; by the incoming President, Mr. H. B. Herr, and by Hon. Thomas B. Bryan and Mr. E. L. Corthell. Brief and entertaining remarks were made also by Messrs. Artingstall, Davis and Nickerson, and at a late hour the meeting adjourned.

Thomas Appleton, *Secretary.*

Civil Engineers' Society of St. Paul.

January 8, 1894.—Eighth Annual Meeting held at 8.15 P.M. Twelve members present. President Wilson in the chair.

The Librarian was authorized to renew subscriptions to all the periodicals subscribed for by the Society during the past year, and instructed to specify the thin paper edition of *Engineering.* It was also voted that the unbound back numbers of all periodicals received by the Society should be bound as early as

possible, and that coming numbers of the same be bound immediately on completion of the volumes.

The following annual reports were then presented:

Report of the President.

To the Members of the Civil Engineers' Society of St. Paul.

Gentlemen:—I have the honor of submitting herewith the reports of your officers for the past year, and as the same will be read to you I request your earnest consideration.

Our record of work done is not what it should be, and yet I believe that all our members feel a lively interest in the prosperity of the Society. The first half of the year was a very profitable time, and we had a series of interesting papers; during the latter half of the year we have had dull times in the business world, and we have allowed our interest in engineering matters to flag. Now is the time, I think, when we may, to our mutual advantage, inaugurate a better custom. Our room and library offer a convenient and comfortable place for meeting and for the interchange of views and the study of professional subjects, and when business is dull our members have more opportunity to avail themselves of these facilities. It is to be hoped that they will use the room more freely in the future, for the benefits to each and to all will be in direct proportion to this use.

The fact that a large number of the papers read here during the last year have been presented by engineers not members of the Society, should induce us to make an effort in this direction; and I hope that in the future each member of the Society will consider it as much his duty to prepare at least one paper annually as to pay his dues.

With these remarks, I will call your attention to the following reports.

Respectfully,

Geo. L. Wilson, *President.*

Report of the Secretary.

To the President of the Civil Engineers' Society of St. Paul.

Sir:—In accordance with the usual custom and with constitutional requirement, I append the following report:

Six regular meetings, a gain of one over the previous year, and an adjourned session for the discussion of the competitive plans for a tunnel at Duluth, have been held during the past year. Of the seven papers read before the Society, four were submitted by visiting engineers. The list is as follows:

January 9th, "The Marshall Avenue Bridge," by Mr. Jos. S. Sewall, of St. Paul.

February 6th, "Railroad Building in Mexico," by Mr. W. H. Wood, late of Mexico. "Utilization of the Minnehaha Water Power," by Mr. Chas. Steiner, of Minneapolis.

March 6th, "Proposed Tunnel at Duluth, Competitive Design," by Mr. Max Toltz.

March 13th, Discussion of Various Designs for the Proposed Tunnel at Duluth, by Messrs. Estabrook, Munster, Toltz, Keating, Cappelen, Wilgus, Annan, Wilson, Woodman and Stevens.

April 3d, "Proposed Deep Waterway from Buffalo to New York City, and Some Facts About the Suez Canal and the Numerous Projected American Isthmus Canals," by Mr. J. D. Estabrook. (A number of specially invited guests, including ladies, attended this meeting.)

May 1st. "Geology of the Lake Superior Mining Region," by Mr. E. E. Woodman.

November 6th. "Asphalt," by Major J. W. Howard, Superintendent of the Barber Asphalt Paving Co. The public generally were invited to this meeting.)

The Tunnel Discussion and Mr. Estabrook's paper were published in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

On May 1st the Constitution of the Society was amended by the addition of Article XXIV.

MEMBERSHIP STATEMENT.

January 1, 1893	50	Resident members	36
Additions during the year	4	Non-resident members	18
Membership at this date	54		54

Respectfully submitted,

C. L. ANNAN, *Secretary.*

REPORT OF THE TREASURER.

President, Civil Engineers' Society of St. Paul.

SIR:—I have to submit herewith my Annual Report for the year ending December 31, 1893.

RECEIPTS.

Cash on hand January 1, 1893	$ 78 71
Collections	166 19
Total	$244 90

DISBURSEMENTS.

For Journal assessments	$84 50
" subscription to engineering periodicals and book-binding	54 41
" stationery, stamps, etc.	32 75
" book case and care of room	36 50
" contribution to Engineering Congress, World's Columbian Exposition	35 00
	$243 16
Balance on hand December 31, 1893	1 74
Total	$244 90

RESOURCES.

Cash on hand	$ 1 74
Ledger accounts due the Society	345 54
Total	$347 28

LIABILITIES.

None	00

The Treasurer does not wish the smallness of the balance in hand ($1.74) to operate as a reflection upon the financial standing of the Society. Our finances are really in a healthy condition, as is shown by the statement of our resources. The smallness of our balance is due to the fact that the Treasurer has not sent out bills, and an explanation of this is due the Society. Early last fall the Treasurer was

absent from the city about one month, and on his return he was kept busy on engineering work until the latter part of October, when he was taken ill and confined to the house for nearly two months.

Respectfully submitted,

A. O. POWELL, *Treasurer.*

REPORT OF THE LIBRARIAN.

To the President of the Civil Engineers' Society of St. Paul.

SIR :—The total number of volumes in the library at the end of the year was 297. This includes the engineering periodicals for the past year to the number of ten volumes, which are as yet unbound and some of them not entirely completed. A new book-case has added space that will accommodate the increase in the library for the coming year.

The Secretary of the American Society of Mechanical Engineers writes that our library can obtain volumes of reports of that society for the past three years at members' rate, which is one-half the rate to non-members.

Respectfully,

A. MUNSTER, *Librarian.*

After the reading of the annual reports, Mr. S. H. Hedges was elected to membership.

The ballot for officers for the ensuing year resulted as follows:

President, GEO. L. WILSON.

Vice-President, J. D. ESTABROOK.

Secretary, C. L. ANNAN.

Treasurer, A. O. POWELL.

Librarian, A. MUNSTER.

Representative on Board of Managers of the Association of Engineering Societies, C. J. A. MORRIS.

The President appointed Mr. F. W. McCoy to audit the Treasurer's report.

Adjourned at 9.30.

C. L. ANNAN, *Secretary.*

Civil Engineers' Club of Cleveland.

JANUARY 9, 1894.—Meeting called to order at 8 P.M. by the President. Fifty-seven members and visitors present.

The record of the meeting held on December 12, 1893, was read and approved.

The tellers announced the unanimous election of Messrs. E. A. Handy and C. A. Carpenter to Active Membership.

Applications for Active Membership from L. L. Malm and S. T. Dodd were read.

A letter was read from Mr. Frank R. Lander, Secretary of Social Committee of the Ohio Society of Surveyors and Engineers, announcing the coming Annual Convention of that Society, and inviting the members of this Club to attend the several meetings which will be held at the Hollenden Hotel.

It was moved and carried that this Club accept the invitation.

Mr. W. H. Searles presented the following names as a committee to nominate

officers for the ensuing year: E. P. Roberts, G. A. Hyde, W. P. Dittoe, W. T. Blunt, and L. Herman.

Mr. John L. Culley nominated for the same purpose Messrs. C. H. Benjamin, C. W. Wason, I. M. Wolverton, and W. R. Warner.

Mr. F. M. Comstock nominated Mr. E. W. Morley.

Mr. S. J. Baker nominated Mr. C. H. Strong.

The Tellers announced the result of the ballot as follows: G. A. Hyde, 25 votes; L. Herman, 23; E. P. Roberts, 19; E. W. Morley, 18; W. T. Blunt, 17; C. W. Wason, 16; C. H. Benjamin, 17; C. H. Strong, 15; W. R. Warner, 5; I. M. Wolverton, 5; W. H. Searles, 1.

Messrs. W. T. Blunt and C. H. Benjamin having the same number of votes, it was necessary to make a choice between them. Mr. W. H. Searles moved that, inasmuch as Mr. C. H. Benjamin was already a member of the Executive Board, and that making him a member of this committee would necessarily involve his retirement from the Board, Mr. W. T. Blunt be selected for the Nominating Committee. Carried.

Mr. Geo. E. Gifford then presented a paper entitled "The Design of the King Bridge Co.'s New Riveting Shop."

Mr. H. F. Coleman presented for discussion a type of truss recently constructed by him. This was discussed by Messrs. F. C. Osborn, L. Herman, and W. H. Searles.

Meeting adjourned at 9.45 P.M.

FRANK C. OSBORN, *Secretary.*

Montana Society of Civil Engineers.

ANNUAL MEETING, JANUARY 13, 1894.—The meeting was held at the Board of Education Rooms, city of Helena, Montana.

The members in attendance were: Messrs. Haven, McRae, Gutelius, Ryon, F. J. Smith, McNeill, Herron, Hovey, Relf, Wheeler, Foss, Knight, Goodale, Cumming, and six visitors.

AFTERNOON SESSION.

President Haven presiding. The minutes of the November and December meetings were read and approved. Applications for membership from Profs. E. H. McDonald and R. E. Chandler were reported approved by the Trustees, and read; and letter ballots were ordered to be sent out for the next meeting.

Mr. S. T. M. B. Kielland was duly elected to membership. The following officers were elected for the ensuing year:

President, W. A. HAVEN.

First Vice-President, J. S. KEERL.

Second Vice-President, A. M. RYON.

Secretary and Librarian, G. O. FOSS.

Treasurer, A. S. HOVEY.

Trustee for Three Years, W. S. KELLEY.

For Member of Board of Managers of the Association of Engineering Societies, J. S. KEERL.

President Haven then delivered the following address:

The President's Address.

Gentlemen:—In Section 1 of Article 1 of the By-Laws of our Society are these words: "At the Annual Meeting the President shall present a report containing a statement of the general condition of the Society and a summary of engineering progress during the preceding year."

As there is not even a comma in this sentence, it seems to mean that the President shall present one thing and not two things, but I shall take the liberty of dividing it, and first make you a report of the general condition of the Society.

The report of the Secretary herewith submitted shows that our active membership numbers thirty-eight. Several members have been dropped from the rolls during the past year for non-payment of dues, in accordance with the vote of the Society at the last Annual Meeting. As I understand the meaning of Section 7, Article 5, of the By-Laws, any of these members may, upon payment of all arrears, be restored to membership by a majority vote of the members present at any regular meeting. By the rules of other and similar societies the arrearages here intended are those up to the time when the name is dropped from the roll.

Several of these gentlemen have signified to me their desire to reunite with the Society as soon as the state of their finances will allow.

During the year three members have been added to our number, one has been elected to-day, and the names of two more candidates are before the Trustees. The report of the Secretary shows that we are not rolling in wealth, and yet it is a common saying that a man is rich when he owes nobody. As we are not in debt, we may, especially at this time of financial panic, consider ourselves wealthy. At any rate we have not suspended payment nor made an assignment, nor has a receiver been appointed to administer our affairs, and, moreover, the Secretary is so sanguine of the solvency of this Society that he recommends a twenty per cent. reduction of the annual dues, at the same time that he asks for permission to purchase a book-case in which to keep our constantly increasing library, both of which recommendations I endorse.

I take pleasure in informing you that all of the committees I have appointed during the last year have performed all the work required of them. This is a new departure worthy of being made a permanent feature of our Society.

The monthly committees on "Topics," with the sad exception of the committee composed of one of your past presidents, have each produced a paper which has been read before us. One of these committees, indeed, produced two papers, both of which were published in the Journal, and I am glad to see that you have rewarded the faithfulness of this committeeman by electing him to-day to an office of trust and honor.

In an article by Prof. Johnson, published in the February number of the Journal, there is a list of 16 societies and clubs of civil engineers, with a membership of 2,690. The total number of papers read annually before these organizations was 199, giving an average of one paper to every 13½ members. In that list the Montana Society is given as consisting of 50 members and as producing six papers. By this average our society of 38 members should have produced last year about three papers, viz., two long ones and a little one, but it is very gratifying to me to be able to report to you that during 1893, ten valuable papers were read at our meetings, of which four have been published in the Journal, and another is now in the hands of the printer.

At our last Annual Meeting 22 members were present, more than half of our

entire membership, and, as they reside all over a State larger in area than all of New England and the State of New York combined, and some of them even beyond these limits, such a meeting is something to be proud of, especially when we consider that it was known beforehand that there was to be no banquet, no picnic, and no "excursions to points of interest," with the usual concomitants of such jaunts, but simply a meeting for the reading and discussion of papers upon engineering subjects.

Until July the monthly meetings were well attended, and several visiting engineers were usually with us. In July the President and Secretary were both in Chicago, and there was no meeting; but in the fall months, notwithstanding the financial depression which seriously affected all our members, the meetings continued as usual, and at the meeting when your past President, Mr. E. H. Beckler, was made an honorary member of the Society, there was quite a full attendance.

At one of the fall meetings one of our members came from Butte, 70 miles away, on purpose to read to us an interesting paper, offering an example of zeal and of interest in the Society which cannot be too highly praised. Much is said in the proceedings of other engineering societies and clubs about cultivating a social feeling amongst the members. One of the objects of this Society is "to promote social intercourse," and for several years we have had a banquet on the evening of our Annual Meeting, but it seemed to me that these had become expensive, stiff and unsocial gatherings, and last year I recommended to the committee to abandon them for awhile and try the experiment of having a meeting for business and the free discussion of papers or other matters in which we all took a professional interest. I hope, however, that the matter of social intercourse will not be neglected.

Montana in January does not seem a fitting time for making excursions to points of interest. I should be glad to assist in starting a movement in our Society looking to something like the mid-summer convention of the American Society of Civil Engineers, when the members go in force, with their wives and sisters and with other fellows' sisters, and have a good time and get acquainted with each other. Let the Annual Meeting remain, as it is now, the principal business meeting of the Society, in which its policy for the year shall be decided and the actions of its outgoing officers freely criticised, and let the summer meeting bring us together more sociably. Sec. 4 of Art. I of the Constitution provides for such a summer meeting if any three members request it.

A question has arisen as to the meaning of the term, Honorary Member of this Society. Section 5, Article 3, of the By-Laws says: "They shall be subject to no dues or assessments." Section 1, Article 4, of the Constitution reads: "Members alone shall have the privilege of voting." By your unanimous vote you elected Mr. Beckler an honorary member, he having been at the time a member. By becoming an honorary member does he cease to be a member and thereby lose his privilege of voting and all other voice in the conduct of the Society? Suppose hereafter you made some other resident member an honorary member, do you thus deprive him of his rights as a member? Of course, it is plain that when a man not a member is thus honored, we do not confer upon him any rights as a voting member.

The outlook is favorable and the general public has a healthy respect for our Society and its work. In this regard our Society compares well with those in the East.

During the past year, as I have from time to time read the addresses of other presidents (by-the-way these almost invariably have been made by *retiring* presidents, and there is no precedent for the making of an address by a newly elected

president or by one continuing in office), I found several expressions common to them all, such as: "Engineers must assert themselves;" "The public is ignorant of what an engineer is;" "We must instruct the public;" "We must band ourselves together;" "We must assert our prerogatives," etc., etc.

In this connection I often recall the remark of a well-known railroad president. When a case or an opinion was stated to him in emphatic terms, he would reply: "Well, what does the other fellow say?" Now I would ask: What does the public say of engineers? How does the public know that an engineer, or a society of engineers, knows anything about what the public is interested in? Why do engineers complain that they are not oftener consulted? It seems to me that the cause lies in themselves primarily. Engineers habitually act as if their special knowledge and training were a trade secret. They seem to keep themselves aloof as a caste, and seldom take any part in public discussions on any questions of works to be undertaken either by states or by municipalities. We all know that few of us are orators, but all of us can write clear and convincing arguments and statements upon any subject that involves engineering questions, and when engineers do this their papers have great weight in the community and are freely quoted in public meetings and on the street corners; but they seldom write such papers. Engineers separate themselves in this respect from other citizens and wait for somebody to come along and open their mouths and set their hands and brains at work by means of a large fee.

In a discussion before the Boston Society of Civil Engineers (you who read the JOURNAL remember to what I refer), Mr. C. W. Ellis hit the nail pretty squarely on the head in his paper entitled "The Relation of the Engineer to the Public." If engineers will not discuss public questions in the newspapers or in public meetings, as other citizens do, let them do it in the society. The Montana Society is open for the fullest and freest discussions of any subject of interest to the public of Montana. The men who in thirty years have made this State what it is, men who have developed these mines, built these smelters and mills and reduction works, and who have made these beautiful cities where twenty-five years ago there were but barren hillsides and valleys and gulches, these men are not ignorant of what a civil engineer is, but, on the contrary, when any question of public interest arises, they look to the engineer, hoping to be informed about the engineering law. The Montana Society of Civil Engineers is respected by the public, and only last winter, when an important question was before the legislature, dozens of its members asked me: "What does the Montana Society of Civil Engineers think of this proposed law?" Already one or two laws have been passed solely on account of their being recommended by our Society, and one of your committees now has in hand an amendment to the law relating to county surveyors, an amendment which will doubtless be passed by the next legislature.

I trust that the members of our Society will make themselves felt in the community by full discussion, in papers and otherwise, at our meetings during the coming year, and thus show their knowledge, their science and their practical good sense.

Thanking you for your confidence in me, and for the honor of a second re-election to your presidency, I welcome you to our Annual Meeting.

THE SECRETARY'S REPORT.

The Secretary's report for the year 1893 was then read. It showed total receipts for the year amounting to $353.50, and total expenditures $360.85, show-

ing an excess of expenditures over receipts of $7.35. The Secretary stated, however, that over $107.25 of this amount was for bills incurred during the year 1892.

Uncollected dues for the year 1893	$121 00
Balance in Treasury	26 86
Total resources	$147 86

The Secretary recommended that the annual dues be reduced to $6.00 for non-resident members, and $8.00 for resident members.

The Society now has 39 active members, 1 honorary member, and 8 associate members.

The following engineering magazines and periodicals are received regularly, and will be bound and added to the library:

The Engineering and Mining Journal,
The Engineering Record, and
The American Engineer and Railroad Journal.

The report recommended that the Secretary be authorized to purchase a book-case for the Society, and that all the books belonging to the Society be catalogued and a list of them sent to each member. The report was accepted and referred to the Trustees for auditing.

The Treasurer's Report.

The Treasurer's report was then read, showing a balance in the treasury of $26.86, and receipts and expenditures as per the Secretary's report. This report was also received and referred to the Trustees.

Verbal reports were received from the Committee on Library and from the Committee on Membership.

On motion of Mr. John Herron, with appropriate remarks, seconded by remarks from several other members, Mr. Joseph T. Dodge, an associate member, was elected an honorary member of the Society.

The following resolution was unanimously adopted:

Whereas, The General Managers of the Northern Pacific Railroad, and of the Great Northern Railway, have kindly granted transportation to the members of this Society, enabling them to attend, free of charge, the Annual Meeting of the Society.

Resolved, That this Society express to the General Managers, through the local agents of the railroad, its sincere thanks for the courtesy extended.

The following amendment to the By-Laws was offered:

"Section 6, Article 4, By-Laws. The annual dues shall be $6.00 for non-resident members, and $8.00 for resident members, and shall be paid to the Secretary on or before the first meeting in February of each year."

This amendment was received and laid over until the next meeting of the Society.

The Secretary read a letter from N. B. Ringeling, asking that he be allowed to withdraw from membership. The Secretary reported his dues fully paid, and, on motion, Mr. Ringeling's resignation was accepted.

On motion, the Secretary was duly authorized to purchase a book-case for the use of the Society.

It was voted that any active member of the Society, elected to honorary membership, still retains the right to vote as an active member without payment of dues.

Mr. Hovey then stated to the Society that he understood a letter had been received by the United States Surveyor-General of Montana, which indicated that the department was about to make a ruling which would prevent deputy mineral surveyors from practicing in more than one surveying district.

Mr. Hovey stated that for the past few years it had been customary for deputy surveyors in Montana to hold commissions in Idaho, and for the Idaho deputies to hold commissions in Montana. If the new ruling was put in effect, the field in which deputies would be allowed to operate would be very materially contracted.

On motion, Messrs. Hovey, Knight and Wheeler were appointed a committee to report on the subject to the Secretary at the evening session.

Mr. Knight, in behalf of the Butte members, extended an invitation to the Society to hold a meeting in Butte, and it was decided to hold such a meeting there during the coming summer.

The Society then adjourned until 7.30 P.M.

Evening Session.

The meeting opened with President Haven in the chair. Mr. John Herron presented a paper entitled, "Conduct of Repair Work in Railway Emergency Cases."

After the reading of this paper and discussion of the same, the report of the committee heretofore appointed by the Chair to consider the custom of allowing Deputy Mineral Land Surveyors to practice, as heretofore, in other States, territories, and survey districts than the one in which they reside, was read by Mr. Knight, chairman of said committee.

The report was as follows:

"Your committee, appointed to consider the matter of a United States Deputy Mineral Land Surveyor holding appointment or commission in more than one State, territory, or survey district, beg to report that they have performed that duty, and have to recommend that this Society, by its officers, petition the honorable Commissioner of the General Land Office to allow Deputy Mineral Surveyors to practice in any States upon filing the necessary bonds and receiving an appointment from the Surveyor-General of the United States, or district, without regard to their places of residence."

The Society then entered upon a discussion of certain questions relating to the measurement of water under the State statute.

It was generally conceded that the statute was very indefinite, and that different engineers could secure results varying at least 50 per cent. in the amount of water measured, by employing different methods, all of which would comply with the wording of the statute.

After the discussion, which lasted about an hour, President A. M. Ryon, of the State College of Agriculture and Mechanic Arts, formerly Professor of Civil Engineering at the College of Montana, was appointed a committee of one to make experiments and to report to the Society some more satisfactory method of measuring water than that provided for in the statute.

Mr. Goodale, Superintendent of the Gangon Mine at Butte, then addressed the Society in regard to the matter of the corrosion of iron pumps and columns, caused by the presence of sulphuric acid in the water pumped from the Butte mines. He

stated that in the Gangon mine a considerable quantity of water constantly leaches down through the old stopes, and in so doing it seems to become more or less impregnated with sulphuric acid, which acts on the columns and pumps.

"There is quite a difference in the character of the water in the different parts of the mine. In the silver mines the water is not particularly troublesome, but in the copper mines there is a great deal of trouble. In the Gangon mine we have very troublesome and corrosive water. Four years ago it gave no great trouble. We often used it for boiler feed, but found that its action on the mud drums made it necessary for us to discontinue using it for that purpose.

"It was still giving us no trouble in the pumps and columns, but as time went on and the mine was opened up, there was more of this low-grade ore for the water to leach through, and the present year has brought us face to face with the necessity of using some other material than iron for the columns.

"Two and a-half years ago we put in a 7-inch column to throw this water to the surface, and for awhile no marked corrosive action was apparent, but during the last spring the iron was very evidently corroded, and the surprising thing about it is, that this action showed first at the top of the column. As it went on, more leaks occurred, until one 15-foot length of pipe had 13 clamps upon it.

"It was fully determined that we must use something besides iron, but just what ought to be used is a serious question. There is one copper column in the mines in Butte, but copper is so expensive that it is almost out of the question for us to think of duplicating that column. There is also one brass column, 5 inches in diameter, but I understand there is some objection to that. I think it is probable that we will have to come down to using iron pipe lined with wood, which is the cheapest method I know of for keeping the water away from the iron."

The President appointed Messrs. Hovey and Knight as two additional members of the committee to prepare a memorial on the life of past President Col. W. W. DeLacy.

The following gentlemen were appointed committees to secure papers to be read before the Society: Mr. Relf, of Helena, for February; Mr. Gillie, of Butte, for March, and Mr. Griffith, of Helena, for April.

On motion of Mr. Foss, the Society extended a vote of thanks to the Board of Education for the use of its rooms.

On motion of Mr. McNeill, the Society extended its thanks to gentlemen who presented papers before the Society.

No further business offering, the Society thereupon adjourned.

G. O. Foss, *Secretary.*

Engineers' Club of Minneapolis.

January 15, 1894.—The annual meeting was held at the Public Library at 8 p.m., President F. W. Cappelen in the chair. Messrs. Cappelen, Howe, Andrews, Pardee, Lee, Dunham, Coe, Nexsen, Pike, Sublette, Hoag and Hazen, members, and Mr. E. H. Ahara, guest, were present. The eight gentlemen first named had taken advantage of the arrangements made for supper at 6.30 p.m. at Thomas' Café.

Minutes of meetings of November 16h, and December 18, 1893, were read, and, on motion, approved as read.

Mr. Wm. A. Pike, as member of the Board of Managers of the Association of

Engineering Societies, made a verbal report, in which he stated that he had received a telegram asking whether he could attend a meeting of the Board in New York, and that he had subsequently received a letter from Prof. J. B. Johnson stating that Mr. John C. Trautwine, Jr., had offered his resignation as Secretary of the Association, that if this resignation were not accepted and if the office of the Secretary and the publication of the Journal were therefore removed to Philadelphia, the expenses of publication would be $500.00 more than they were last year, and that Mr. John M. Weston had made a proposition which would practically make them about $600.00 less than those of last year. Mr. Weston's proposition was to make a contract to print the Journal and furnish it to members of the associated societies at $2.50 per annum each, for the next three years, and for $2.25 each for the succeeding three years.

Mr. Pike desired to have an expression of the sentiments of the members of the Club before he voted on this subject. After some discussion and after replies to questions relative to the matter, Mr. Geo. A. Andrews moved:

That the sentiment of the Club is at present in favor of the retention of Mr. Weston as Secretary, and that our representative be requested to vote accordingly, unless developments should in his estimation so change the situation that the interest of our Club would be promoted by other action. Seconded.

Mr. W. R. Hoag moved to amend by adding: That this Club prefers that, if practicable, the contract with Mr. Weston should not be for a longer time than three years. This was accepted by the mover of the original motion, which was then carried, as amended.

The report of the Secretary was then read, and it was moved that it be accepted and that the thanks of the Club be extended to the incumbent for the efficient manner in which the duties of the office have been performed.

The report of the Treasurer was read, showing total collections $123.50; expenditures, $89.23; balance on hand, $34.27. Due from members, $41.00; total assets, $75.27, all but $4.50 probably collectible. Liabilities about $71.00. It was moved that the report be accepted and that the thanks of the Club be extended to the Treasurer for his able financial management during the hard times. Carried.

The report of the Librarian showed that he had had bound the complete volumes of the JOURNAL in his possession, and stated in detail the additions made to the library. On motion, the report was accepted, with the thanks of the Club.

Mr. Hoag moved that the Secretary be authorized to have a list of the members printed as suggested in his report. Carried.

The President remarked that the report of the Secretary had fully stated what had been done during the year. He believed that an excursion during the coming year, in conjunction with the St. Paul Society, and possibly with a visit from the Duluth and Superior Clubs, would add to the interest of the members in the Club, and urged that in order to make the Club of value to all, dependence must not be placed entirely upon its officers, but that each member must help.

Mr. Sublette moved that the rules be suspended and that the Secretary be instructed to cast the ballot of the Club for the re-election of all the Officers of 1893 to the same offices for 1894. Seconded and unanimously carried.

The Secretary having cast the ballot as directed, the President announced that the following gentlemen had been elected as the officers for 1894:

President, F. W. CAPPELEN.

Vice-President, J. M. HAZEN.

Secretary and Treasurer, ELBERT NEXSEN.

Librarian, A. B. Coe.

Member of Board of Managers of Association of Engineering Societies, Wm. A. Pike.

After considerable discussion it was moved and unanimously adopted, that an assessment of Two Dollars semi-annually on each member be made to cover the regular expenses of the Club, and that the Secretary and Treasurer be directed to collect the same.

Mr. Coe asked whether any member had made any measurements of the Intramural Railway at the Exposition. He had paced the length of the spans and thought they were about 22 feet. He questioned whether their factor of safety was not very small. Other members stated that in many other structures at the World's Columbian Exposition a low factor of safety had been used, in consideration of their temporary nature.

The amendment to Article I of the By-Laws, changing time of holding the meeting nights to the Third Monday of each month at 8 o'clock, was then unanimously adopted, attention having been drawn to the fact that not one of those desiring a change from Thursday had been present at meetings which had been called on other evenings for the purpose of enabling them to come and make the change.

Mr. Andrews moved that it was the sense of the meeting that the arrangements for supper should be repeated. Carried.

Mr. Andrews stated that he proposed to give the results of certain Radiator Tests made by his firm, and desired the members to be prepared to discuss the following questions:

1st. Whether it is correct to base the calculation and construction of radiators upon the theory that the perfection of radiation made a perfect radiator? 2d. Is the heat given off only in rays perpendicular to the surface of the radiator at every point, or is it given off in every direction from each point?

In answer to a question, Mr. Andrews stated that in a large apartment house, the expense had been reduced to 75 cents per square foot of radiating surface per season, that in office buildings one square foot of radiating surface would suffice to heat about 60 cubic feet of space, and that in stores one square foot would provide for 180 cubic feet of leakage per hour.

The name of Edwin Hugh Ahara was proposed for membership by Mr. E. Nexsen, and seconded by Mr. I. E. Howe. Mr. Ahara's address is: care of Minneapolis Esterly Harvester Works, residence 74 N. 12th St.

On motion adjourned.

Elbert Nexsen, *Secretary*.

1620 S. E. 4th St., Minneapolis, Minn.

Engineers' Club of St. Louis.

392d Meeting, January 17, 1894.—President Crosby called the club to order at 8.20 p.m., in its new quarters, 1600 Lucas Place. Forty members and twelve visitors present.

The minutes of the 391st meeting were read and approved.

The Executive Committee reported the doings of its 154th meeting, announcing the signing of a contract with the Missouri Historical Society for new quarters for two years. The following programme for 1894 was announced:

January 3d—Street Railways, Winthrop Bartlett.

January 17th—Street Railways, Geo. R. Olshausen.

February 7th—Washington University Testing Laboratory, J. B. Johnson.

February 21st—The Manchester Ship Canal, John Dean.

March 7th—The New Water Works; I, General Features, M. L. Holman.

March 21st—The New Water Works; II, The Extension, S. Bent Russell.

April 4th—The New Water Works; III, New Machinery, J. A. Laird.

April 18th—The New Water Works; IV, Quality of the Supply, Robert E. McMath.

May 2d—The New Water Works; V, The Problem of Filtration, Robt. Moore.

May 16th—Punching as a Means of Testing Structural Steel, Theodore L. Condron.

September 19th—Sharp Curves in Railroad Yards, E. A. Hermann.

October 3d—Motions of Soaring Planes, Dr. C. M. Woodward.

October 17th—A Method of Determining Sewage Pollution of Water, Charles C. Brown.

November 7th—Progress in Steam Engineering, Col. E. D. Meier.

November 21st—Report of Committee on Smoke Prevention, W. B. Potter, chairman. Appointment of Committee on Nomination of Officers for 1895.

December 5th—Annual Meeting. Reports of officers and committees. Nomination of officers for 1895.

December 19th—Announcement of result of election. Address of retiring president.

The recommendation of the Executive Committee that Messrs. I. A. Smith and Nils Johnson be reinstated on payment of back dues was, on motion, approved. An application for membership was announced from Mr. A. J. Hammond, city engineer, Frankfort, Ind

Mr. Geo. R. Olshausen then addressed the Club on the subject of Street Railways, dealing particularly with special work in track construction. He called attention to the great improvements which had been made in this direction in the last four years. He exhibited drawings of standard switch and crossing construction, and described a method of designing spiral easement curves, a method which he had found very satisfactory in practice. The Union Depot Company uses a rail weighing 100 pounds per yard on curves, and a 75-pound rail for straight track.

Messrs. Crosby, Johnson, Laird, Hermann, Bryan, Kinealy, McCulloch and Crow took part in the discussion. The necessity for a better form of brake was discussed, the present types described and the practical experience with each stated. It was shown that what is needed is a quick and powerful application of the brake at first, while the car is still running fast. It was shown that if the rail is well bonded there is no necessity for supplemental return wires or for other grounds. The electrolytic effect of the return current on water mains was explained, and it was thought this could be remedied by thoroughly connecting the rails to the pipes by copper wires.

Mr. Morrell, Engineer of the Lindell Railway Company, was present, and stated that in his opinion the best return is to weld each pair of rails together with two 0000 copper wires, and then to connect the rails to the generators at the station without any other attempt at grounds.

Adjourned. Wm. H. Bryan, *Secretary.*

ASSOCIATION
OF
ENGINEERING SOCIETIES.

PROCEEDINGS.

Engineers' Club of St. Louis.

ANNUAL ADDRESS.

BY ROBERT MOORE, RETIRING PRESIDENT.

(Read December 20, 1893.)

Members of the Engineers' Club of St. Louis:

As we review the year now drawing to a close, the Columbian Exposition, which, during this period has so greatly delighted and surprised the world, stands out also as the event of greatest interest to the engineer. This is true not only because of the beauty of the grounds and buildings and the marvelous story of the world's progress told by their contents, but also for the reason that in it all the engineer played so prominent a part. Take away the work of the engineer and not only would many of the buildings have been stripped of their contents; the structures themselves would have been resolved into dreams impossible of realization. What were the departments of Mining, Machinery, Electricity, and Transportation but exhibitions of the work accomplished in so many special departments of engineering? Indeed, with the exception of a few departments, such as those of Horticulture and the Fine Arts, the whole exposition might be described, in the words of Telford's well-known definition of the work of the engineer, as an exhibit of the progress which has been made in "directing the great sources of power in Nature for the use and convenience of man."

Limiting our view to a few of the most salient points, and to work accomplished since the exposition at Philadelphia, in 1876, the most striking single feature is, perhaps, the enormous development which in this brief period has taken place in the utilization of the electric current. Prior to 1876 the uses of electricity were limited to the telegraph and the electro-plating of metals. Inventors were at work upon the problem of utilizing the electric light, but so far without reaching the point of either mechanical or commercial success; and the telephone, which had been patented a few months before (in February, 1876), was exhibited at the Philadelphia exposition as a curiosity. Now the electric light is found everywhere, in our houses and on the streets, and is rapidly superseding all other means of illumination, whilst by its aid the recent exposition was lighted with a brilliancy and beauty beyond even the dreams of 1876. The telephone also has become a necessity in every center of business, and for cases in which a written record is

desirable, the telautograph, which, as witnessed at Chicago, transmits an autographic message, will soon, no doubt, find a field equally wide. The electric current is in daily use also for the welding of metals, the driving of machinery, and the propulsion of street railway cars. The army of street-car horses, whose occupation has thus been destroyed, has already, by competing for work in other lines, depressed the horse market beyond precedent, and it is now quite probable that this grand "army of the unemployed" will, in a few months, be increased by the horses now engaged in the propulsion of canal boats. As an instrument for the transmission and distribution of power, the electric current seems destined easily to outstrip all rivals. In forecasting its future development, however, it is well to bear in mind the fact, often lost sight of, that electricity is not a prime mover, but, like a belt or a line of shafting, is a mere transmitter of force, so that we are still as dependent upon the water wheel and the steam engine for the primary impulse as we were fifty years ago. The dynamo and the electric motor are in fact not producers but consumers of power, and their use is justified only where it can be positively shown that greater consumption is prevented by such use. For small and intermittent powers this can in most cases be easily shown, but for large powers the case is quite different, and, until the electric current shall be produced directly from the fuel, in which direction no substantial progress can yet be recorded, our large mills and factories, our pumping stations and our railway trains will, no doubt, continue to be driven by steam engines.

But only the most rapid glance at the recent Exposition was required to show that the steam engine which will be used for these purposes will be of a type very different from that in use at the Exposition of 1876. Then the compound engine was rarely seen except on steamships, where the importance of reducing the consumption of coal is at a maximum. But at Chicago it was clearly the prevailing type for all uses. For pumping water or for driving machinery hardly anything else was to be seen, and even for propelling locomotives it was quite evident that in the judgment of locomotive builders the compound engine is to be the engine of the future. The economy due to the use of high initial steam pressures, which by this means can be employed, is now universally admitted; and the compound engine is destined to prevail upon the land as it has already prevailed upon the sea.

In the matter of great single engineering works, the record of the past year is shorter than that of many previous years. In railroad construction, The Siberian railway, which Russia is now pushing across the continent of Asia to the Pacific Ocean, is almost the only great work now in progress. In our own country, the building of railroads has been limited mainly to short branch-lines, or to lines necessary for the development of existing systems. On one such line, the Colorado Midland Railway, a new tunnel, one and three-quarter miles in length, and at an elevation of nearly 11,000 feet above the sea, has, after three years of work, been driven through the main continental divide of the Rocky Mountains. By this work seven miles of distance and seven hundred feet of elevation are saved. In the aggregate, probably 3,000 miles of new road have been added to the 175,000 miles of railway already existing here, an amount which, in any other country, would be considered large, but which, as compared with the 12,879 miles added in 1887, is exceptionally small. This reduction in the increment of the railroad mileage of the country is an evidence not only of the adverse financial conditions of the past year, but also of the fact that, in its main features, the railway system of the United States is approaching completion. The day for the construction of long lines of new railway

is rapidly hastening to a close, and the work of the railway engineer will hereafter be largely confined to the possibly less interesting but not less important work of developing and improving the existing lines by the construction of heavier bridges, additional tracks, better forms of permanent way, better signaling apparatus, and safer as well as more comfortable cars. The amount of work of this class, which has already been accomplished on our main trunk lines, is such that speeds of sixty or even one hundred miles per hour are now attained with as much ease and safety as attended speeds half as great on the same roads fifteen or twenty years ago. On the great majority of our railways, however, an amount of work, quite equal to that already spent, will have to be done, in order to secure as safe and rapid handling of passenger trains and as prompt dispatch of freight, as are accomplished by the English lines.

Passing from the railways, we have to note the completion, during the present year, of the ship canal from Liverpool to Manchester, in England, thus joining, by means of a new commercial highway, two points connected 125 years ago by the Duke of Bridgewater's canal, built by James Brindley, and again sixty years later by the historic railway, on which George Stephenson first practically demonstrated the capabilities of the locomotive engine. The new canal, which has been in progress since 1885, and has just been opened during the present month, is designed for vessels up to 600 feet in length and 26 feet draught, in other words, for all but a few of the very largest. Its cost, for thirty-five and one-half miles, has been about $75,000,000, or more than double the original estimate. A considerable part of this enormous cost has been due to excessive parliamentary and right-of-way expenses, in which are included the purchase of the old Bridgewater canal, a purchase rendered necessary by the opposition of its owners to the construction of its new rival. One of the most interesting works of the new canal is a revolving draw span aqueduct, which takes the old canal over the new one, and replaces one of the boldest and most novel of the works of Brindley. The new canal will, in effect, make Manchester a seaport, and may transfer to that city the control of the cotton trade which now centers in Liverpool.

Another ship canal completed during the present year is one through the Isthmus of Corinth, joining the Gulf of Corinth and the Ionian Sea to the west of it, with the Ægean Sea. Though less than four miles in length, this work has involved the moving of eleven million cubic yards of material and an expenditure of nearly fourteen millions of dollars. It is one of the oldest projects of its class, dating back to the time of the Cæsars, but, like the Suez Canal, it had to await for its realization the age of steam, with the improved machinery and methods of the present time.

Still another ship canal, now rapidly nearing completion, is the North Sea and Baltic canal, which, for nearly seven years, has been under construction by the German government. This canal, sixty miles in length, extends through the Province of Holstein at the southern end of the Danish peninsula, from the harbor of Kiel, on the Baltic, to Brunsbüttel, at the mouth of the Elbe, and will furnish an inland route wholly on German territory, from the North Sea to the Baltic, in place of the long detour, within range of the guns of foreign forts and navies, which has been heretofore required.

It is to be a sea level canal without locks except those at the ends, which are intended as a protection against the fluctuation of the tides. Its cost is estimated at $39,000,000, and already over a hundred million cubic yards of material have been removed. Its completion, which is expected during the coming year, will mark a new step by the Empire of Germany toward the military, political and commercial supremacy to which she aspires.

Turning our eyes westward to the American continent we are struck with the fact that here, as in Europe, the largest engineering projects are those for the construction of ship canals. Passing over the Panama scheme, which, since my former address as retiring President in 1885, has more than realized the fears of failure then expressed, and has carried down in melancholy wreck the once honored name of De Lesseps, the most important by far of all the engineering enterprises now before the people of the United States is that for the construction of a ship canal across the Central American isthmus by way of Lake Nicaragua. After thorough and careful surveys, which demonstrated its entire feasibility, the work of actual construction was about two years ago begun by a private company of citizens of the United States. Adverse financial conditions have recently forced the Nicaragua Company into insolvency and caused a suspension of the work. For the sake of the great commercial interests, both for this country and for the world at large, which are involved in the completion of this great international highway, it is greatly to be desired that this suspension may not be of long duration; and in the opinion of many, with whom I fully agree, the same motives of commercial and political policy which forced England, after the completion of the Suez Canal, and in spite of her bitter opposition to its construction, to acquire a controlling voice in its affairs, should lead the Government of the United States to take now a like control of the canal at Nicaragua. Should this be the outcome of the present suspension, the latter will prove to have been a most fortunate event for the country at large.

Coming still closer home we find under construction another great canal of unique character, a canal in which our own city is deeply interested. This is the one now being built by the city of Chicago for the purpose of diverting the waters of the Chicago River from Lake Michigan southwardly by way of the Illinois River into the Mississippi. To this end a canal about 33 miles in length with a minimum width of 160 feet and a mean depth of water of 26 feet is now under construction. The capacity of the canal is expected to be about 15,000 cubic feet per second, and its cost is estimated at from $20,000,000 to $30,000,000. The prime object of this work is to purify the city water supply by keeping out of Lake Michigan the sewage which now enters it through the Chicago River, to do effectively and on a grand scale what has already been done partially and on a small scale for twenty-five years or more by the pumping station at Bridgeport. A secondary and quite subordinate end is the opening of an improved highway of navigation, for it is claimed that by removal of the dams already existing in the Illinois River and by the construction of suitable works a channel depth of 14 feet can be opened from Lake Michigan to the Mississippi River. This end, however, has had little or no weight in determining the construction of the canal. It is being built as the "Main Drainage Channel" of "The Sanitary District of Chicago."

Whether, when this canal is completed, the lake will be so thoroughly freed from pollution as to make its water safe to drink without filtration, is a question not wholly free from doubt; but its effect in destroying the Illinois River as a potable stream and forcing filtration upon all who are obliged to use it, including the city of St. Louis, is a matter beyond all doubt; and when it is taken into account that this pollution of an important river is to be accomplished by breaking through a natural divide into a foreign water-shed, it seems clear that it is a measure which nothing short of absolute necessity can justify.

Another hydraulic enterprise of less doubtful utility and of very great significance for the future, is that now nearing completion for the utilization of the power

of the Niagara Falls. This work, which has been in progress since October, 1890, is designed to use about 1,060 cubic feet of water per second, or 4 per cent. of the total volume of the river. With an available fall of 140 feet and an efficiency of 75 per cent., this will give about 125,000 horse-power, 5,000 of which are to be developed at once. For this purpose a canal has been taken out of the river on the American side about one and one-quarter miles above the Falls. On this canal are to be located the various power houses. The general plan of the power stations involves wheel pits about 160 feet in depth. These are connected by short tunnels, with a main tunnel which acts as a common tail-race for all the stations. This tunnel is 21 feet in height by 19 feet in width and 6,700 feet in length, and discharges into the river at a point 1,100 feet below the Falls. The velocity of the water in the tunnel is expected to reach 25 feet per second, which requires that the work throughout must be of the highest class. The lining of the tunnel at the outfall is made of steel plates, but for the rest of its length it is lined with four rings of brick made especially for this use. How well it will withstand the abrading action of such a high velocity time will tell. The distribution of power is to be made very largely by means of electric conductors, and the circuits already in contemplation embrace the city of Buffalo as well as a section of the Erie Canal, where it will be used for the propulsion of boats. For the production of the currents three dynamos of 5,000 horse-power each are now under construction. The results of this enterprise will be watched with great interest, and the probabilities are, that it will be the forerunner of a large number of similar works for the enrichment of the world by the utilization of enormous water-powers now running to waste.

Amongst events of engineering interest which have signalized the present year one worthy of special remembrance is the International Engineering Congress, which assembled at Chicago during the first week of August. This congress, which was international in fact as well as in name, brought together a larger number of engineers of different nations, and more papers of permanent value, than any similar meeting in the history of the world. The wide scope of the subjects considered is clearly indicated by the titles of the sections into which the congress was divided. These were the sections of Civil Engineering, Mechanical Engineering, Mining and Metallurgical Engineering, Engineering Education, Military Engineering, Marine Engineering and Naval Architecture, to say nothing of a separate conference on Ærial Navigation, having for its chairman a past-president of the American Society of Civil Engineers. The section which, next to that of civil engineering, produced the largest number of papers was that of marine engineering and naval architecture, and this fact illustrates the awakening of our nation to the importance of the navigation of the high seas, an awakening which forms a marked feature of the present time and is full of promise for the future of our country.

Of the events of this congress one of the most significant was the action taken by the American Society of Civil Engineers upon a proposition looking to the appointment of a special committee to consider the propriety of the adoption by the society of a code of ethics for the profession. This proposition was one which had been under discussion in the society and in the engineering journals for a considerable time. In March last the Boston Society of Civil Engineers, the oldest of the local clubs, made this general subject a special order for one of its meetings, and the series of seven papers in which were discussed the various aspects of the engineer's duties to those with whom he is brought in professional contact, forms an interesting chapter in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES for September last. The discussion at the Chicago meeting was rather brief, but the

vote of 54 to 11, by which the proposition was rejected, gave conclusive evidence that those present had made up their minds and that further discussion was not required.

This vote and the events which led to it are indicative, not of any lack of interest in the subject of professional duty, but of an unwillingness to delegate to any corporate body the responsibility for decisions which devolve rightly upon the individual himself.

The professional code of the physician dates from a time when it was the fashion, both in church and state, to relieve the individual of all responsibility except that of obeying the mandates of a superior officer. To think or act for oneself, in almost any line of thought or action, was considered unsafe. The craftsman was restrained by the laws of his guild, the citizen by the edicts of his sovereign, the scholar by the thoughts of those who had gone before him or by the commands of the priesthood. Experience since then has shown that the citizen can be safely trusted with freedom, and that truth is safer when thought is free and doubt is unrestrained, than when it is committed to the keeping of any organized body that the world has ever seen. So in the matter of professional ethics, no society or organization can safely take the place of the individual conscience. Let there be the fullest and freest discussion of the duties of the engineer in every relation of life. Let this be a subject for discussion in engineering societies and of instruction in engineering schools, but let there be no legislation upon it. Every code, like every creed, is sure in time to become a fetter.

"New occasions teach new duties,"

and there can be no doubt that the course heretofore adopted and deliberately affirmed at Chicago, a course which throws upon each individual the duty of deciding rightly upon each new occasion as it arises, and holds him rigidly responsible therefor, is the one which will most certainly maintain and advance the dignity of our most honorable profession.

393d Meeting, February 7, 1894.—The Club was called to order by President Crosby at 8.15 p.m., at 1600 Lucas Place. Thirty-nine members and eleven visitors were present.

The minutes of the 392d meeting were read and approved.

The Executive Committee reported the doings of its 155th meeting, accepting the resignation of George R. Mann to date January 1, 1894, and approving the applications for membership of A. J. Hammond and M. L. Mitchell, who were balloted for and elected.

Mr. Julius Pitzman moved that a committee of five be appointed by the President to confer with a similar committee appointed by the St. Louis Chapter of the American Institute of Architects, to consider with them the feasibility of a system of boulevards in the central part of this city, and to report to the Club.

This motion was seconded by Mr. Hermann, and after discussion by Messrs. Moore, Flad, Seddon and Dean, was carried.

The President appointed on this committee Messrs. Julius Pitzman, Chairman; W. S. Chaplin, W. B. Potter, C. M. Woodward and Robert Moore.

Prof. J. B. Johnson then addressed the Club in regard to the Testing Laboratory of the Washington University, where an extensive series of timber tests are now in progress under the auspices of the Forestry Division of the Department of Agriculture. The construction and uses of the various testing machines were

explained, after which the meeting adjourned to the laboratory itself, on Seventeenth and St. Charles Streets, where cross-breaking tests were made on yellow pine beams 4 x 4 and 8 x 14, and a compression test on a yellow pine column 10 inches square and 12 feet long.

Adjourned. WM. H. BRYAN, *Secretary.*

394TH MEETING, FEBRUARY 21, 1894.—The Club was called to order by President Crosby at 8.20 P.M., at 1600 Lucas Place. Twenty-five members and three visitors were present.

The minutes of the 393d meeting were read and approved.

The Executive Committee reported the doings of the 156th meeting.

The special committee appointed at the last meeting to consider the subject of boulevards in the central part of the city, submitted the following report:

ST. LOUIS, MO., February 21, 1894.

B. L. Crosby, Esq., President Engineers' Club.

DEAR SIR:—The undersigned committee, appointed at the last meeting to confer with the committee appointed by the St. Louis Chapter of the Society of American Architects concerning the establishment of a system of boulevards in the central portion of the city, begs leave to report that it first held a conference to examine into the scheme, and, being unanimously in favor of the plan, arranged for a meeting with the committee of architects, which meeting was held last Monday.

The project was carefully discussed and the joint committee adopted a resolution to enlarge the committee by asking the Merchants' Exchange, the Real Estate Exchange, the Commercial Club, the Mercantile Club, the Noonday Club and the Mechanics' Exchange, each to appoint a committee of five members, making forty in all; and it was further resolved to have the committee of forty select ten additional members who do not belong to the aforesaid organizations.

The location of boulevards was discussed and the different routes as shown on the map (to be exhibited) were favorably considered, but it was decided to delay action and to have the committee of fifty members determine and agree upon a plan.

A committee consisting of Prof. C. M. Woodward, Mr. W. S. Eames and Mr. Julius Pitzman was appointed to interview the Mayor and to ascertain his views and wishes with reference to the scheme.

Your committee stated at said meeting that it was not authorized to act on behalf of the Society of Engineers, until a plan of action was submitted and approved by it, and whereas we believe it to be of the utmost importance for the city of St. Louis to have a system of boulevards established and to widen the streets surrounding the new Union Depot and leading to same; and whereas we further believe that it is the duty of the societies of engineers and architects and will inure to their benefit to give such scheme a strong and enthusiastic support; therefore we recommend that immediate action be taken, so as to avoid unnecessary delay.

Very respectfully,

JULIUS PITZMAN,
W. S. CHAPLIN,
C. M. WOODWARD,
ROBT. MOORE.

It was moved and seconded that the report be received and adopted as the sense of the Club, and that the Committee be authorized to continue to act in the name of the Club as outlined in the report. It was moved and seconded, as a substitute, that the report be received and the Committee continued. After discussion by Messrs. Johnson, Taussig, Pitzman, Moore, Crosby, Russell, Ockerson, Condron, and Flad, the substitute was lost and the original motion adopted.

The Secretary read a formal letter from the Secretary of the joint meeting of the Committee of Architects and Engineers, outlining the work done and progress made. The letter was received and ordered filed.

Mr. John Dean then read a paper on "The Manchester Ship Canal," discussing the preliminary work, the engineering features and the commercial effect of the canal. The original company was organized in 1882, and after mature deliberation adopted the lock plan. The Parliamentary grant was twice refused, but was finally passed in 1885, when $2,000,000 had been spent on preliminary work. The estimated cost was $50,000,000, and the actual $70,000,000, which included a great deal of work not originally contemplated. The city of Manchester issued $25,000,000 in bonds to aid the enterprise, and it holds a controlling interest until these bonds are paid off. Manchester lies 35 miles east of Liverpool and its elevation is 60 feet higher. The length of the canal is 35½ miles; the maximum cut was 66 feet, and the average 35 feet. There were 52,000,000 cubic yards of excavation, of which 12,000,000 were in rock. Capt. J. B. Eads was consulted regarding the original plans, and made some suggestions which were adopted and which proved of great value. The canal is 26 feet deep, and 28 feet on lock sills. Its width for part of the way is 120 feet at bottom, and 170 feet at the water line; and for the rest of the way 170 feet at the bottom and 220 feet at the water line, affording ample room for the largest ships to pass at any point. Being lighted throughout by electricity, it is used by night as well as by day. The clearance allowed under bridges is 75 feet, and the time of passage six to seven hours; 3,000,000 tons are annually moved each way, at less than half of the railroad rate. The paper was discussed by Messrs. Ockerson, Moore, Pitzman, Wheeler and Johnson.

Adjourned. WM. H. BRYAN, *Secretary.*

Western Society of Engineers.

311TH MEETING, FEBRUARY 7, 1894.—The 311th meeting was held at Club Room A, Grand Pacific Hotel, Chicago, at 8 P.M., February 7, 1894, with President Herr in the chair and seventy-five members and guests present.

The reading of the minutes of the previous meeting was dispensed with.

The Secretary reported the action of the Board of Directors as follows:

Since the last meeting of the Society the Board of Directors has held two meetings, viz.: On January 17th and February 7th.

Messrs. Wallace C. Evans and Almon D. Thompson were elected to membership of the Society.

The application of Mr. Arthur E. Rutledge, of Rockford, and Mr. Isaac S. Chesbrough, of Chicago, were received and laid over under the rules.

The resignations of Messrs. Albert W. Smith, A. F. Robinson, J. C. Spencer, and Jas. C. Hallsted were received and accepted.

Messrs. Benezette Williams, A. Gottlieb, John Nichol and Thos. Appleton were appointed the Board of Managers to represent this Society in the Association of Engineering Societies, Mr. Morehouse having declined a re-appointment.

On motion duly seconded, the report of the Board of Directors was received and placed on file.

The Secretary reported the death, on January 31st, of Mr. Wm. H. Lotz, a member of the Society since 1880.

The Secretary reported the following contributions to the library:

From Mr. W. O. Seymour: "Report of the Board of Railroad Commissioners of Connecticut, for 1893."

From I. S. Chesbrough : Nine volumes of "Report of Department of Public Works, Chicago."

From Mr. C. J. Roney : 28 bound volumes, 24 unbound volumes, 133 pamphlets, 1 large map of the United States, 1 large four-sheet mineral map of Mexico, a set of large atlas sheets and two portfolios of Maps of the United States Surveys, and a number of loose maps, 58 plates of locomotives, tenders and cars of the Royal Prussian Railways, 266 papers of the "Transactions of the American Institute of Mining Engineers."

From Mr. Granville Kimball : 2 Trade Catalogues.

From A. C. McClurg & Co.: Catalogue of Holiday Books.

From Mr. James S. Cobb : "Classified Illustrated Catalogue of Library Bureau."

On motion duly seconded the report of the Secretary was received and placed on file.

President Herr : In the matter of new business the Board of Directors have received several communications for the Society, and has ordered them presented to the Society to-night. As they are not very long, I suppose it would be best for the Secretary to read them, that being the only way in which the Society can get the sense of them.

The Secretary then read a communication from Mr. Charles Hansel, suggesting the formation of a club, to be called the Chicago Construction Club, and a prospectus of the same.

Also a communication from Mr. E. L. Corthell, suggesting the formation of an International Institute of Engineers.

Also a communication from Mr. Charles J. Roney, recommending that the library of the Society be catalogued and indexed, and that efforts be made to increase the number of volumes, plates and maps, by obtaining reports from National and State governments, etc.

After remarks by the President and by Messrs. Wallace, Harding, Webster, Cooley, Purdy, Barnes and Randolph, it was moved and seconded,

That a committee of seven, with the Secretary as secretary of the committee, be appointed to consider and report upon a plan for the reorganization of this Society upon a higher and broader basis than the present.

The motion was put to vote and unanimously carried.

President Herr : The Secretary reports the death of our fellow-member, Mr. Wm. H. Lotz. Are there any remarks to be made on this report?

Mr. Reynolds : I move that a committee of three be appointed to draw up a memorial. The motion was seconded and carried, and the President appointed Messrs. Raeder, Horton and E. L. Heidenreich.

President Herr: Gentlemen, you will recall that the Secretary mentioned in his report a very important donation to the library. I am sure it must have been pleasing to you, as it was to myself, to hear of it. It looks as though some of us at least mean to do what we can to help the Society along. The donation I refer to was from Mr. Roney, and others were from Mr. Seymour and Mr. Chesbrough.

It was moved by Mr. Hunt that the Secretary be instructed to tender the thanks of the Society to the donors. Seconded and carried.

President Herr : I am not aware whether these gentlemen are all present, but wherever they are, I tender them the thanks of the Society for their interest and liberality, and I hope that their worthy example will be imitated by all of you.

Gentlemen, as most of you know, the title of the paper for this evening is "A Method of Using High Explosives as a means of Propulsion in Aërial Navigation." I think this subject very appropriate for this evening, because it is "way up," it is high, it is the direction in which we are going, and I think it will be very interesting as a matter to which many engineers have given perhaps little attention, and I believe they will be surprised to learn that so much has been done in the direction of Aërial Navigation as you will hear of this evening. I have the pleasure of introducing to you the writer of this paper, Dr. Pynchon, of Chicago.

Dr. Pynchon then read the paper, an abstract of which will appear in future proceedings.

President Herr: Gentlemen, I believe that, as I expected, most of you have heard something new, and I am sure we have all heard something very entertaining. I feel that we are greatly indebted to the reader of the paper for giving us the pleasure of listening to so well prepared a study of this difficult subject. The paper is now before you for discussion; and no doubt there are points in it that you will not all agree with or upon which you may want further light.

Captain Hunt: As the Doctor is not a member of the Society, but our guest, I think it is quite proper, Sir, and it gives me great pleasure, to move that the thanks of the Society be tendered him for his very interesting and instructive paper.

The motion was seconded and unanimously carried.

On motion the meeting adjourned.

The President has appointed the following members as the committee on reorganization: Mr. John F. Wallace, Chairman; Messrs. E. L. Corthell, L. E. Cooley, Chas. Hansel, James F. Lewis, Wm. Sooy Smith, Hosea Webster and Thomas Appleton.

Previous to the meeting some forty members sat down to an informal dinner at the Grand Pacific Café, where opportunities were afforded for conversation and for becoming better acquainted with one another. This social annex to the regular meeting was considered very interesting and met with such success that it will, so far as practicable, be made a feature of all future meetings.

Erratum.—Through an unfortunate oversight, the report of the proceedings of the annual meeting omitted to state that Mr. Richard P. Morgan had declined to allow the use of his name as a candidate for President of the Society. Although this fact was duly announced by mailing postal cards to all of the members of the Society, it should appear on record, and the Secretary makes this correction at this time.

Death.

Our ex-President, Mr. Abraham Gottlieb, died very suddenly on Friday, February 9th. A committee consisting of Messrs. O. Chanute, C. L. Strobel, C. R. Schniglau, S. G. Artingstall, W. M. Hughes, H. A. Rust and Chas. Fitz Simmons were appointed to represent the Society at the funeral.

Thomas Appleton, *Secretary.*

Civil Engineers' Club of Cleveland.

Tuesday, February 13, 1894, Chamber of Commerce Rooms.—Meeting called to order at 7.45 by Vice-President Howe. Sixty-two members and visitors present.

The record of the meeting held on January 9th was read and approved.

The tellers announced the unanimous election to Active Membership of Mr. Samuel T. Dodd.

An application for Corresponding Membership was read from Mr. Henry E. Riggs, Toledo, Ohio; and applications for Active Membership were read from Prof. Chas. F. Mabery, and from Messrs. Isaac K. Pierson and Edward G. Lane.

The following report was presented by the committee appointed by order of the Executive Board, February 6th, "to investigate the employment of engineers by the Park Commission."

To the Civil Engineers' Club of Cleveland:

Your committee, appointed by order of the Executive Board, February 6, 1894, "to investigate the employment of engineers by the Park Commission and to ascertain if any action by the Club, as a Club, would be desirable or advisable," respectfully report and recommend that the following be entered upon the records of the Club, and that a copy be sent to the Board of Park Commissioners:

WHEREAS, The facts following have been obtained through the courtesy of the President and Secretary of the Board of Park Commissioners, the Board has entered into a contract with Ernest W. Bowditch, of Boston, to act as its Chief Engineer, for a term of three years, at a salary of $4,000 per year for one-fourth of his time, he being expected to keep that time on record hour by hour, and at the rate of ten hours per day. He is also allowed $500 per year for expenses, and $3,000 per year for his resident assistant, out of which latter item Mr. Bowditch retains a bonus. If the Board for any cause shall dispense with the services of Mr. Bowditch, it must forfeit him $1,000.

A few field propositions have been tendered to and accepted by Cleveland men. They are entirely subordinate, with no special credit or responsibility attached, and none of them paying over $5 per day.

The original records of the engineering work are the property of the Chief Engineer, and the Board must pay for any copies it desires for its own files.

The Board, previous to the appointment of Mr. Bowditch, received several applications for the position of Chief Engineer from local engineers. The Board had no special reason to suppose that the applicants were incompetent to fill the position of Chief Engineer, but it made no attempt to investigate in any way their fitness for the position, either by allowing their appearance before the Board, or otherwise. To all appearances, the employment of Mr. Bowditch was a foregone conclusion.

The Board, in September, 1893, before the appointment of the Chief Engineer, received the following petition, which was entered upon the record as having been received. No further comment appears on the record and nothing was ever heard of the petition by the signers. We cannot learn that it was ever discussed or accorded any consideration.

To the Honorable Board of Park Commissioners:

In view of the fact that your honorable body has been authorized to expend $1,000,000 for the purposes mentioned in the Act of the Legislature entitled, "An Act to provide a Board of Park Commissioners, etc.," passed April 5, 1893, the undersigned citizens of Cleveland respectfully represent that it is their sense and desire that a Chief Engineer of your honorable body shall be appointed from among the prominent and capable Civil Engineers of this city, of whom there are many well qualified by their training and experience to conduct large works of engineering such as will be required; among them being several former Chief Engineers of railroads, City Civil Engineers, Ex-Principal Assistants and others whose talents and ability are well known. As the purely engineering features

comprise fully ninety per cent., and only a small portion of the work is the designing of landscape effects, we are desirous that home talent be employed, as we feel there is no outside talent superior to that which can be found within the city. For the small proportion of the work requiring the services of a landscape architect, should the Board be unable to find such talent within the city, they would be justified in securing the services of outside parties of acknowledged ability to act in connection with their Chief Engineer.

Signed by ten members of the American Society of Civil Engineers, various members of the American Institute of Architects, The American Society of Mechanical Engineers, and the American Institute of Electrical Engineers, by the President and Cashier of nearly every bank in the city, and by numerous other citizens of well-known integrity. Among the 79 signatures are those of Prof. J. W. Langley, Wm. Chisholm, W. S. Jones, H. B. Corner, J. J. Sulivan, W. W. Baldwin, Jno. F. Whitelaw, Jno. H. Farley, E. R. Date, C. C. Bolton, Jas. Barnett, Chas. L. Murfey, F. O. Spencer, T. W. Hill, E. W. Moore, D. Leuty, H. R. Newcomb, J. F. Rust, O. G. Kent, H. B. Gibbs, J. B. Parsons, Stevenson Burke, T. P. Handy, T. C. Matteson, Jno. Vevera, J. C. Alexander, T. K. Dissette, Dan P. Eels, W. P. Johnson, J. Colwell, H. P. Eels, D. Z. Norton, Jas. Pickands, G. S. Russell, J. L. Severance, L. H. Severance, W. H. Barris, W. B. Hale, Myron T. Herrick, M. Raynolds, T. H. Brooks, L. C. Heckman, L. O. Rawson, D. R. Taylor, J. B. Hanna, N. P. Bowler, D. O. Caswell, J. D. Ketcham, C. B. Beach, Chas. Wesley, R. H. Greary, Jas. Gibbons, L. Malm. Ed. S. Page, F. H. Eggers, W. J. McKinnie, L. C. Kane, Wm. L. Rice.

Whereas, Vastly the largest proportion of the engineering work called for under said law will be in the line of constructive engineering, the artistic effects appearing as a very small percentage of the work, and

Whereas, This Club believes that in this city are resident many engineers fully capable of carrying on said constructive work economically, rapidly and successfully,

Resolved, That the Civil Engineers' Club of Cleveland takes this occasion to enter its protest against the discourteous action of said Board in giving no consideration to the claims of other applicants than the one appointed; and to aver its belief that had the Board fully considered these claims, it would have found a competent Chief Engineer from among the many Resident Engineers of ability and reputation who were applicants, and if found necessary or advisable might have then called in some specialist in landscape effects in a consulting capacity.

Respectfully submitted,

Wm. T. Blunt, *Chairman*,
Jas. Barnett,
Harley B. Gibbs,
C. P. Leland.

An amendment to the above was offered by Mr. E. P. Roberts to the effect that a copy of the above be sent to the Executive Board of the Chamber of Commerce. Amendment and resolution were both adopted unanimously.

The Nomination Committee reported through its chairman, Mr. G. A. Hyde, the following nominations for officers for the ensuing year: For President, Ambrose Swasey and C. S. Howe; for Vice-President, Jno. N. Richardson and F. A. Coburn; for Secretary, Frank C. Osborn and Frank H. Neff; for Treasurer, C. P. Leland and J. C. Wallace; for Librarian, C. H. Benjamin and Albert H. Porter; for First Director, Chas. W. Wason and Chas. F. Lewis; for Second Director, Norman B. Wood and Walter Miller.

Mr. Blunt then presented the following resolution:

Whereas, The following letter appeared on the 8th of February, 1894, in one of the daily papers of this city:

THE COST OF EDUCATING ENGINEERS.

To the Editor of the Leader:

The city of Cleveland has been educating engineers at a fearful cost to the taxpayers of the city, and I believe that the Park Commission are not only prudent but wise in employing an engineer that has the experience and the ability. When the city put in the water works, Wm. Case (the then Mayor), went to Kentucky for a water works engineer, and he found Mr. Scowden, a "high-priced engineer." Mr. Case made no mistake in that case. After the water was put in, the next work was sewerage. Then the city sought home talent, and the city paid thousands upon thousands for useless sewers. Not one sewer in the then city of Cleveland would drain a cellar. Next came the paving of the streets. Here again the city paid enormous sums for educating home talent. Now we have good engineers in that line, as good as can be found, and yet taxpayers would have saved enough by employing experts at the beginning to employ the Boston engineer during the rest of his natural life. Home talent came into play again in the building of the viaduct, which cost almost double what it should have cost. Home talent, without experience in the line of engineering required, is the most expensive. I simply desire to say that in my opinion the Park Commission have acted wisely in employing an engineer of experience in "the line."

February 8, 1894. AN OLD ENGINEER.

Resolved, That the Civil Engineers' Club of Cleveland hereby record its condemnation of the unjust and unwarranted attack on the reputation and works of the engineers of this city, most of whom are members of this Club; also, its chagrin at learning that a man claiming the right to sign himself "An Old Engineer" should so far forget the loyalty due to his profession, and the pride which should accompany its high calling, as to hold up to public gaze a few of the unfortunate incidents in the work of the municipal engineers of Cleveland in the past as samples of the work of the present generation, and avowedly as an argument against the employment of engineers resident here at the present day.

Resolved, That this Club believes that the engineering talent in this city will not suffer by comparison with that of any other city of its size, and is fully worthy of the confidence of the public.

Mr. Walter P. Rice and George M. Reid then spoke in the highest terms of Mr. Samuel H. Miller, the designer of the Superior Street Viaduct, and expressed their regret at the unwarranted attack on his ability as an engineer. Messrs. E. P. Roberts, W. R. Warner, and W. H. Searles then spoke on the subject, taking the ground that, as the communication was an anonymous one, the proper course for the Club would be to ignore the communication, and on being put to a vote the resolution was lost.

Mr. W. R. Warner moved that a committee be appointed to arrange for the usual annual banquet. The following committee was appointed: C. P. Leland, Chairman; W. L. Otis, F. A. Coburn, A. E. Brown, W. H. Searles, E. P. Roberts, and J. L. Gobeille.

After an inquiry as to whether we were to have ice-water or wine to drink at the banquet, and some remarks by Messrs. J. L. Gobeille and W. T. Blunt, it was moved and carried that the details of the banquet be left entirely with the committee.

Colonel Smith addressed the meeting with regard to the action of the Banquet Committee of last year.

The Committee appointed to prepare the memorial of our late member, John H. Sargent, reported as follows:

Your Committee appointed to prepare a memorial of our late and highly esteemed member, John Harris Sargeant, who died October 20, 1893, beg leave to report as follows:

Mr. Sargent was born in Lockport, N. Y., March 7, 1814. He came to Cleveland when only four years of age and lived here for six years. He then returned East to secure better advantages for a technical education. At the age of nineteen he returned to Cleveland and took up his life-work of Surveying and Civil Engineering.

His marked ability and untiring devotion to his profession, as evidenced by the various public works on which he had been employed, won for him a wide reputation as a thorough and practical engineer.

He was engaged on the location and partial construction of one of the first railroads begun in Ohio, "The old Ohio Railroad." He was connected with the original surveys and final location and construction of the Cleveland and Columbus Railroad, and was Chief Engineer of the Air Line of the Michigan Southern and Northern Indiana Railroad during its construction. He was connected with the rebuilding of the old line, and with the construction of various other railroads and public works.

He was a member of the City Council in 1859, and was elected City Civil Engineer in 1860. He took an active interest in all public works, always advising that they should be built with a view to the future wants of a growing city. He was a member of the Water Works Board in 1869, and held various other offices of public trust. He was among the first to become a member of the Club, having joined in April, 1881.

We have all been pleased and profited by listening to his many papers read before the Club, and to his wise and interesting discussions of the various subjects that have been presented from time to time.

We submit the following resolutions:

Whereas, It has pleased God, in His wise Providence, to remove from us our beloved brother, John Harris Sargent, therefore,

Resolved, That in his death we are deeply impressed with the sense of the great loss which this Club has sustained.

Resolved, That we tender to his bereaved family our heartfelt sympathy.

C. H. Strong,
N. P. Bowler,
G. E. Hartnell,
Committee.

It was moved and carried that this report be adopted and spread upon the records.

Mr. H. C. Thompson then read a paper entitled "Shall Grades and Alignment be Improved, or Weight of Locomotives be Increased on Railroads?" which was discussed by Messrs. C. P. Leland, Hosea Paul, W. H. Searles, E. A. Handy and W. C. Jewett.

Prof. A. A. Skeels then read a paper entitled "A New System of Electric Block Signals," which was discussed by Messrs. W. H. Searles, W. T. Blunt, S. T. Dodd, E. P. Roberts, and C. S. Howe.

On account of the absence of Mr. George E. Gifford, the discussion on the paper which was read at the January meeting was postponed until such time as he should be present.

Meeting adjourned at 10.45 p.m.

Frank C. Osborn, *Secretary.*

Civil Engineers' Society of St. Paul.

February 5, 1894.—The regular meeting of the Civil Engineers' Society of St. Paul was held at the society rooms at 8.15 P.M., and directly after a dinner at the Commercial Club, in which eighteen members participated. After the approval of the minutes of the previous meeting, the President called upon Mr. C. A. Hunt, who explained in a general way the repairs now in progress on the dam at St. Anthony Falls.

Mr. Hilgard then gave his theory of the failure of a portion of the roof of the St. P. & N. P. tunnel at Westminster Street. The tunnel has a clear width of 28 feet, and in that part under consideration was quite flatly arched with four concentric rings of brick at the crown instead of with five, as had been provided by its designer after brick had been ordered to be substituted in this section in place of the cut stone used in other sections of the tunnel. In the course of seven years the arch at the under side of the crown had settled about one foot, and a cross-section of the intrados showed a slightly sinuous line. Careful inspection failed to prove any definitely measurable displacement or settlement of the vertical sidewalls. In settling, the brick rings separated from one to three inches as near as might be on the line of greatest pressure, and but slightly elsewhere. For instance, at the crown the greatest open space had formed immediately below the external ring, and at haunches above the internal ring. The passage of this line of principal separation through intermediate rings in offsets corresponding to the radial joints was marked by longitudinal cracks.

In Mr. Hilgard's opinion the settling of the arch was due to the gradual grinding out of mortar from both ring and radial joints effected by the vibration of the roof and the general jarring caused by the frequent passage of heavy trains puffing through the tunnel on a heavy grade, for the traffic through the tunnel continued during its construction.

Furthermore, this section of the arch, although resting on heavier sidewalls than those supporting the stone arch, lacked the lateral support and surcharge of the contemplated filling, the construction of which had been indefinitely postponed by the rival railroad corporation owning the ground crossed, which had insisted on the building of the tunnel entirely across its right of way through the Trout Brook hollow. The weight and bulk of this fill, if made, would have considerably checked the vibrations. Mr. Hilgard suggested that the lesson taught by this case was, that for similar arches under like conditions cut stone should be used instead of brick; or, should brick be a necessary resort, cut stone blocks should be inserted at proper intervals, in order to form the absolutely necessary bond between the several rings; and, further, that arches exposed to vibration and jarring should be built considerably heavier than the load alone would require.

Mr. Münster followed Mr. Hilgard with a few remarks on the measurement of water in connection with the test of a pumping engine of 6,000,000 gallons capacity, and distributed blue print copies of an original diagram for weir measurements, giving quantities in cubic feet per second from gauge readings for all weirs up to ten feet in length.

President Wilson then produced some topographical maps of the Connecticut State Survey, which would have been examined with more interest but for the lateness of the hour.

C. L. Annan, *Secretary.*

Engineers' Club of Minneapolis.

FEBRUARY 19, 1894.—Regular meeting at Public Library called to order by William A. Pike, C. E., who by unanimous vote occupied the chair in the absence of the President and Vice-President.

The minutes of the meeting of January 15th were read and approved.

Upon motion of Mr. Andrews, seconded by Mr. Abbott, the Secretary was requested to cast the ballot of the members for Edwin Hugh Ahara as a member. The motion was carried unanimously, and Mr. Ahara was thereupon declared elected a member.

It was moved, seconded and carried that the Secretary be directed to write to Mr. Fletcher requesting him to use his influence to change the law in regard to the cost of mailing engineering club literature.

Mr. William A. Pike, as member of the Board of Managers of the Association of Engineering Societies, made another report on the question of publishing the JOURNAL, stating that the Chicago members had thought there should be a change, that Prof. J. B. Johnson had given reasons chiefly financial for retaining Mr. Weston, that he (Mr. Pike) had voted for Mr. Trautwine, who received 9 out of 13 votes, that the JOURNAL will therefore be removed to Philadelphia, and that Mr. Trautwine will assume the Secretary's duties. Mr. Weston had submitted a proposition to publish the JOURNAL by contract, but the proposition was declined.

Mr. George C. Andrews gave an informal talk on Steam Heating, describing a series of tests on radiators, and calling attention to the variation in the amount of heat developed, as shown by the increase of temperature in an hour, the duration of tests and the amount of condensation shown. By the aid of the blackboard he described the shapes and arrangement of the sections.

The discussion embraced the difference in outdoor temperature at the times when different tests were made, and the desirability of finding a rule or proportion which would allow a comparison of the several experiments on the same conditions.

The room in which the experiments were made had one brick wall with two windows opening to the outer air, while the other three walls were of wood or glass, and the temperature on the outer sides of these three walls was about 65°.

In closing his remarks Mr. Andrews called attention to the absurdity of requiring those putting in a steam heating plant to guarantee the heating of the building when the two things upon which the efficiency of the plant depends, viz., the proper construction of the building itself and that of the chimney which furnishes the draft for the boiler, are entirely beyond their control.

Present: Messrs. William A. Pike, A. B. Coe, G. C. Andrews, G. D. Shepardson, E. T. Abbott, E. H. Ahara and E. Nexsen.

Adjourned about 11.30 P.M.

ELBERT NEXSEN, *Secretary.*

Boston Society of Civil Engineers.

JANUARY 24, 1894.—A regular meeting of the Society was held at its rooms, 36 Bromfield Street, Boston, at 7.45 P.M., President John R. Freeman in the chair; 73 members and 28 visitors present.

The record of the last meeting was read and approved.

A committee, consisting of Messrs. Henry Manley, E. S. Dorr, C. F. Allen, T. H. Barnes, and F. W. Hodgdon, was chosen to nominate officers for the ensuing year.

On motion of Prof. Allen, it was voted to have the usual Annual Dinner, and to refer the arrangements for the same to the Board of Government, with full powers.

Mr. Fred. Brooks gave notice, in writing, of the following amendment to By-Law IX. Strike out, in the second line, the word *six*, and insert in its place the word *seven*, so that the first two sentences of the by-law shall read: "The entrance fee shall be ten dollars. The annual dues shall be *seven* dollars for members and associates residing within thirty miles of Boston, and four dollars for those residing at a greater distance, payable in advance at the Annual Meeting."

The Librarian announced that arrangements had been made for a series of informal meetings in the Society's Library, on the Wednesday evenings in the month other than that assigned to the regular meeting, that the evenings, until further announced, would be devoted to the subject of sewerage, and that at the first of these meetings, on January 31st, an account would be given of the Sewerage of Newton.

The Secretary then read a memoir of Joseph Coulson, a member of the Society, prepared by Messrs. R. A. Hale and F. S. Hart.

The subject of the evening's discussion was then taken up, viz.: The Organization of a City Engineer's Office, and the Best Methods of Carrying on its Work.

Mr. A. F. Noyes gave an abstract of his paper, read at the last meeting, on the Organization of the Office. He was followed, on the same subject, by Messrs. L. M. Hastings and W. E. McClintock. The Secretary read a paper by Mr. O. F. Clapp, on the Organization of the City Engineer's Office of Providence. Mr. G. A. Kimball read a paper on the Management of a City Engineer's Office, which was discussed by Messrs. McClintock and Stearns. Mr. John C. Olmsted read a paper on the Relation of the City Engineer to Public Parks. Mr. William E. McClintock read a paper on the City Surveys and Maps, and was followed by Mr. Fred. Brooks on rectangular coördinates and uniformity of datum plane of levels in their relation to municipal surveys.

Adjourned. S. E. Tinkham, *Secretary.*

February 6, 1894.—A special meeting of the Society was held at its rooms, 36 Bromfield Street, 7.50 p.m., President John R. Freeman in the chair; 42 members and 27 visitors present.

The meeting was called for the purpose of continuing the discussion on the work of a City Engineer's Office. Mr. Dexter Brackett opened the discussion with a short paper on the Water Works Department of the Office. The paper was discussed by Messrs. Noyes, Fuller, Manley, Shedd and others.

Mr. G. A. Nelson read a paper describing the survey made of the city of Lowell, and Mr. E. W. Shedd described the survey now in progress for New Bedford. The subject was discussed by Messrs. McClintock, Whitney and Brooks.

The subject of indexing and arranging plans was then taken up. The Secretary read an account by Mr. O. F. Clapp of the method in use in Providence, R. I., and Messrs. Kimball, Adams, and Hammett spoke on the subject. Mr. H. D. Woods exhibited a drawer for holding plans, which was used in the City Engineer's Office at Newton. Mr. J. T. Desmond described the work of the City Engineer's

Office in Haverhill, and Mr. Henry Manley closed the evening's discussion with a short paper on bridge inspection and maintenance.

Adjourned. S. E. TINKHAM, *Secretary.*

FEBRUARY 21, 1894.—A regular meeting of the Society was held at its rooms, 36 Bromfield Street, at 7.45 P.M., Vice-President Albert F. Noyes in the chair; 62 members and 27 visitors present.

The record of the last regular meeting, and that of the special meeting of February 6th, were read and approved.

Mr. Luther H. Bateman was elected a member of the Society.

Messrs. Charles T. Main and Henry B. Wood were appointed tellers to canvass ballots for officers at the Annual Meeting.

The following amendment to By-Law IX, proposed in writing at the last regular meeting, was unanimously adopted. Strike out, in the second line, the word *six*, and insert in its place the word *seven*, so that the first two sentences of the by-law shall read: "the entrance fee shall be ten dollars. The annual dues shall be seven dollars for members and associates residing within thirty miles of Boston, and four dollars for those residing at a greater distance, payable in advance at the Annual Meeting."

Mr. Manley gave notice, in writing, of the following amendment to By-Law VI. Insert, after the word "members," in the last sentence, the words "or from the members of the Society at large," so that the sentence shall read: "The Board of Government shall appoint from its members, *or from the members of the Society at large*, the representatives on the Board of Managers of the Association of Engineering Societies, to which this Society is entitled in addition to the Secretary."

Mr. H. B. Wood read a memoir of Charles W. Drake, a member of the Society.

Mr. Thomas F. Richardson was then introduced and read a very interesting paper, describing the Manitou and Pike's Peak Railway, which was illustrated by a number of lantern views.

The rest of the evening was pleasantly occupied in examining a large number of very beautiful views of scenes in the Arctic region and in Japan, which Mr. Fitz Gerald had thrown upon the screen.

After passing votes of thanks to Mr. Richardson for his interesting and valuable paper, and to the Commissioners on the Extension of the State House for courtesies shown members during the visit to the State House this afternoon, the Society adjourned. S. E. TINKHAM, *Secretary.*

Association of Engineering Societies.

PROCEEDINGS.

Montana Society of Civil Engineers.

February 10, 1894, Regular Monthly Meeting.—The meeting was called to order by President Haven. There were present seven members and two visitors. The minutes of the Annual Meeting, held January 13, 1894, were read and approved.

Votes on the election to membership of Prof. R. E. Chandler and Mr. R. H. McDonald were canvassed, and it was found that twelve votes had been cast, all in the affirmative.

A letter from Col. Dodge was read, thanking the Society for its action in making him an honorary member.

The matter of revising the system of books, and of suggesting a plain and simple method of book-keeping for the Society, was referred to the trustees.

A paper entitled "Masonry Lining at Mullen Tunnel" was read by Mr. H. C. Relf. Mr. Relf showed by plans and drawings the method pursued in constructing this lining, the manner of putting in the concrete of which the walls are made to the springing of the arch, and the method used in constructing the arch resting on this concrete. Mr. Relf also explained the use of a cement mixer employed on this work.

The paper was very interesting and was enjoyed by all the members. Its salient points were discussed at some length.

On motion, the Society adjourned until the next meeting, to be held March 10th.

G. O. Foss, *Secretary.*

March 10, 1894.—Regular Monthly Meeting, held at the office of Messrs. Sizer & Keerl. The meeting was called to order by President Haven. There were present five members and one visitor. The reading of the minutes of the last meeting was postponed until the next meeting.

The following amendment to the By-Laws was unanimously passed:

Sect. VI, Art. 4, of the By-Laws is hereby amended to read as follows: "The annual dues shall be $6.00 for non-resident members and $8.00 for resident members, and shall be paid to the Secretary on or before the first meeting in February of each year."

Mr. Haven submitted correspondence with Senator Power, in relation to the

Manderson-Hainer Bill extending the privilege of second-class rates of postage to the publications of incorporated educational institutions, etc.

An amendment to this bill is proposed making it embrace also the publications of engineering societies.

Mr. E. H. McDonald was appointed a committee to present a paper at the May meeting of the Society.

A discussion took place in reference to the interpretation by United States General Land Commissioner's office of the law in reference to the appointment of deputies in two different States.

Mr. Beckler, an honorary member, addressed the Society.

No further business offering, the Society adjourned.

G. O. Foss, *Secretary.*

Civil Engineers' Society of St. Paul.

March 5, 1894.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8 p.m. Sixteen members and three visitors were present. The minutes of the previous meeting were approved. The following communications were ordered placed on file:

Report of Mr. Benezette Williams, retiring Chairman of the Board of Managers of the Association of Engineering Societies, dated February 6, 1894.

Report of the General Executive Committe of Engineering Societies, Columbian Exposition. Transmitted February 21, 1894.

Circular of Chairman J. B. Johnson, as to matter for the Journal of the Association of Engineering Societies, dated February 23, 1894.

The President appointed Messrs. Morris and Münster as a Committee on Resolutions relative to the retiring Chairman of the Board of Managers of the Association.

The President and the Treasurer were authorized to compensate as usual the custodian and janitor of the City Hall for the care of the Society's room.

Mr. C. J. A. Morris informally addressed the meeting on the subject of Coal Docks and Coal-handling Plants. He illustrated his theme by maps, plans, photographs, etc., of the belt railway and coal dock of the Northwestern Coal Railway Co., now building at Superior, and of various excavating, conveying and coal-handling devices. The belt line, as projected, will intersect all the railroad lines entering Duluth and Superior, of which there are at present six. The dock will be formed by filling to an average depth of ten feet a tract of more than 75 acres, to be enclosed by cribs of 12″ x 12″ timber, hemmed in by a row of 60-feet piles driven to 4-feet centers. The cribs are 22 feet deep and 24 feet wide, and are sunk in 250-feet sections with material (principally sand) raised by a hydraulic dredge capable of moving at least 300 cubic yards of solid matter per hour. The dredge consists of two scows of 5½ feet draft, connected by a hinge joint. The end of the 20-inch suction pipe carries a revolving cutter, which masticates anything in in its way except solid rock. It ranges vertically 28 feet, and horizontally 80 feet, by the swinging of the smaller scow, the main boat (95 feet long) being anchored by fore-and-aft spuds. If the dredge is swung from the forward spud, a range of 150 feet is secured. A 400 horse-power engine works the pump (centrifugal) and cutter. Material may be economically carried 3,500 feet through the 18-inch delivery pipe. The method of handling the coal on this dock has not been definitely planned.

Adjourned at 10 p.m. C. L. Annan, *Secretary.*

Boston Society of Civil Engineers.

Annual Dinner, March 6, 1894.—The twelfth annual dinner of the Society was served at Young's Hotel, Boston, at 6 o'clock P.M. One hundred and twenty members and guests were present. President John R. Freeman sat at the head of the table, having on either hand, as guests of the Society, Prof. F. R. Hutton, of Columbia College, Secretary of the American Society of Mechanical Engineers; Mr. John C. Trautwine, Jr., President of the Engineers' Club of Philadelphia; Prof. Ira N. Hollis, of Harvard University; Mr. W. E. Parker, Agent of the Pacific Mills, Lawrence, and Mr. H. S. Carruth, Secretary of the Metropolitan Park Commission.

After cigars had been lighted, President Freeman called the members to order and congratulated them upon the present condition of the Society as contrasted with that of fifteen years ago, showing an increase in membership from about 80 to nearly 330, and in average attendance from 12 to about 80.

Prof. Hutton was the first speaker. He dwelt upon the fact that the engineers of to day are becoming more and more specialists. It is now impossible for one man to be eminent in every line of engineering. Another difficulty of to-day is to be found in the fact that engineers are now, more generally than heretofore, entering into the employ of large corporations, and much of the experimental data accumulated by them is now held as proprietary matter and not permitted to be published. The engineering organizations should look to it that the material gathered in this way is made available.

Mr. Henry M. Howe, the retiring President of the American Institute of Mining Engineers, spoke of the advancement made in the manufacture of steel and the peculiar qualities inherent in that metal. His message to the civil engineers from the mining engineers was, Tell us what are the values of the physical properties which you need in steel for your uses.

Mr. John C. Trautwine, Jr., brought the greeting of the Engineers' Club of Philadelphia, and remarked that although his city had followed many years in the wake of her eastern sister in forming an engineering organization, her Club now claims a membership exceeding that of any other local engineering society in America.

Prof. Hollis spoke of the work of the Lawrence Scientific School at Harvard College, and of the determination of President Eliot that this should in no way be second to any other department of the university.

Mr. William E. Parker was introduced as the representative of one of the largest textile manufactories in the world. He spoke principally of the importance of industrial engineering and of its intimate relation with all other branches of the profession.

Prof. William T. Sedgwick told of the work of the Massachusetts State Board of Health. He spoke particularly of the municipal water filter, which has been in use at Lawrence, Mass., since last October, and stated that Mr. H. F. Mills, the engineer member of the Board, deserved much credit for the success of this undertaking, which had caused a great decrease of typhoid fever in that city.

Prof. George F. Swain, a member of the Boston Subway Commission, described in brief the plans of the commission to free the streets of the present crowded car traffic, and at the same time secure a measurable degree of rapid transit.

Mr. H. S. Carruth spoke of the work accomplished by the Metropolitan Park Commission. The Blue Hill reservation of 4,000 acres and the Middlesex Fells of

3,000 acres have been already secured. The aim is to keep these reservations in their wild state and to preserve them as free roaming grounds for the people forever. It is also proposed to still further extend the system, especially by securing one of the beautiful beaches just outside the city limits.

The speech-making was closed by a few remarks from Messrs. Desmond Fitz Gerald and Henry Manley.

ANNUAL MEETING, MARCH 21, 1894.—The annual meeting of the Society was held at its rooms, 36 Bromfield Street, Boston, at 7.50 o'clock P.M. President John R. Freeman in the chair, 86 members and visitors present.

The record of the last meeting was read and approved.

Messrs. Austin B. Fletcher, Perry Lawton, Henry C. Mildram, Harold Parker, Cecil H. Peabody, Henry O. Peckham, Thomas F. Richardson, Albert F. Sargent, Jr., Franklin A. Snow and Richard H. Tingley were elected members of the Society.

The Secretary read a communication from the General Committee, Engineering Headquarters, World's Fair, transmitting the thanks of the German Engineering Society for courtesies shown its members visiting the World's Fair. The communication was placed on file.

The Secretary presented, for the Board of Government, a communication from the General Committee, Engineering Headquarters, World's Fair, returning to this Society $55, this being the unexpended balance of the contribution to the fund for maintaining the headquarters at Chicago during the World's Fair. The Board recommended that the members of the Society be notified that 10 per cent. of the money subscribed to this fund had been returned, and that each subscriber be paid his share on application to the Treasurer; any money, however, not called for before June 1st, to be added to the permanent fund of the Society. On motion the recommendation of the Board was adopted.

The Board of Government reported on the communication from the Engineers' Club in St Louis, in relation to the exchange of members, and recommended that the following by-law be adopted:

Any member of any other Society in the Association of Engineering Societies, in good standing, may become a member of this Society, when duly elected as described in By-Law 7, without paying the entrance fee, and with a release from the annual dues for such period, not over one year, as he may show by certificate he has paid in advance in the Society from which he comes.

The President presented and read the annual report of the Board of Government, which was accepted.

The reports of the Treasurer and of the Secretary were read and accepted.

Mr. Bradford, for the Committee on Weights and Measures, reported progress, and asked that the committee be given until the next meeting to report. On motion the committee was continued as at present constituted.

The Committees on National Public Works and on Permanent Headquarters reported progress.

The Committee on Excursion submitted a report, which was accepted.

The Librarian presented the report of the Committee on the Library, which was accepted.

On motion of Mr. Stearns, it was voted that the question of the continuance of the several special committees and the selection of the membership thereof, with the

exception of the Committee on Weights and Measures, be referred to the Board of Government with full powers.

The amendment to By-Laws 6, proposed at the last meeting, was then considered, and, after considerable discussion, was adopted by a vote of 45 to 1, in the following form :

The Board of Government shall appoint from its members, *or from the members of the Society at large*, the representatives on the Board of Managers of the Association of Engineering Societies to which this Society is entitled in addition to the Secretary.

The tellers appointed to canvass the letter ballots for officers, announced the result of the ballot. There being no election of President, Vice-President and Director, the meeting proceeded to choose between the two candidates for each office having the highest number of ballots. As the result of the letter ballot and choice of the meeting, the following were declared elected:

President, WILLIAM E. MCCLINTOCK.

Vice-President (for two years), HENRY H. CARTER.

Secretary, S. EVERETT TINKHAM.

Treasurer, EDWARD W. HOWE.

Librarian, HENRY F. BRYANT.

Director (for two years), FRANK O. WHITNEY.

Mr. William E. Foss read a paper in which he presented some new modifications of formulas for the flow of water in pipes and channels.

Mr. George Bowers, City Engineer of Lowell, gave an account of that city's experience in obtaining a supply of water from driven wells. Mr. Bowers exhibited a large number of photographs illustrating the work, and also showed the screens used. Adjourned.

S. E. TINKHAM, *Secretary*.

ANNUAL REPORT OF THE BOARD OF GOVERNMENT.

FOR THE YEAR 1893–94.

In compliance with the provisions of the Constitution, the Board of Government submits the following report for the year ending March 21, 1894:

At the last annual meeting the total membership of the Society was 310, of which 303 were members, 5 honorary members and 2 associates. During the past year we have lost 13 members; 4 by death, 2 by resignation and 7 by forfeiture of membership for non-payment of dues. There have been added to the Society during the year 24 members by election, and one, whose membership was forfeited for non-payment of dues, has been reinstated on the payment of all arrears, making a total addition of 25, a net gain in membership of 12.

The present membership of the Society is 322, of which 315 are members, 5 honorary members and 2 associates.

The record of deaths among our members is as follows:

Thomas W. Davis, who joined the Society April 16, 1879, died April 22, 1893.
Augustus W. Locke, who joined the Society Oct. 18, 1882, died May 13, 1893.
Charles W. S. Seymour, who joined the Society Oct. 17, 1888, died Oct. 15, 1893.
Frederick H. Barnes, who joined the Society April 18, 1888, died Oct. 16, 1893.

Ten regular meetings and one special meeting have been held during the year, and the twelfth annual dinner of the Society took place on March 6, 1894.

At the regular and special meetings the attendance aggregated 678 members and 265 visitors, a total of 943. The smallest attendance at any meeting was 53 and the largest 111; the average being 86. The attendance at the annual dinner was 118.

During the year the following papers and discussions have been given:

March, 1893.—Relation of the Engineer to those with whom he comes in Professional Contact. Addresses by Messrs. Fitz Gerald, J. W. Ellis, McClintock, P. M. Blake, Tidd, Noyes, A. W. Locke and Manley.

April, 1893.—Bridges Across Western Rivers, Mr. Geo. S. Morison. Illustrated.

May, 1893.—Freezing of Water in Mains to Long Island, Mr. Dexter Brackett. Measurement and Value of Water Power, Messrs. G. A. Kimball, Hastings, Main, Buck and Hale.

June, 1893.—Continuation of the same discussion, by Messrs. Swain, Tidd, Porter, Herschel and Frizell.

September, 1893.—Memoirs of James B. Francis and McGee Grant. Chester Bridge Accident, Mr. George S. Rice. Bursting of Dam at Portland, Mr. J. R. Freeman. Construction of Reservoir Embankments, Messrs. Herschel, Richards, Fitz Gerald and J. H. Harlow.

October, 1893.—Continuation of discussion on Reservoir Embankments by Messrs. Fteley, Edwin F. Smith, J. Waldo Smith and others. Prismatic Stadia-Telescope, Prof. R. H. Richards.

November, 1893.—Notes on Water Power Equipment, Mr. A. W. Hunking. Instruction in Turbines, as given at the Institution of Technology, Prof. Dwight Porter. Memoir of Augustus W. Locke.

December, 1893.—Memoir of Richard Fobes. An Account of the Teredo Navalis in Boston Harbor, Mr. Henry Manley. Second part of paper on Water Power Equipment, Mr. A. W. Hunking.

January, 1894, and Special February.—A series of papers on the Organization of a City Engineer's Office. The Management of the Office, Indexing and Arrangement of Plans and Records. City Surveys and Maps. Records and Plans of the Water Works, of the Sewer Work and Bridge Work. Work in Connection with a Park System. Memoir to Joseph Coulson.

February, 1894.—Manitou and Pike's Peak Railroad, Mr. Thomas F. Richardson. Illustrated. Memoir of Charles W. Drake.

The interest in our meetings and in the excursions has continued during the year, as the increased attendance clearly shows. The use of the Society's room at 36 Bromfield Street by members and friends has been such as to prove that there is a demand for such a place of meeting. It is difficult to say exactly to what extent it has been used by members, as it is known that quite a percentage of those who visit the room neglect to register. The librarian complains that there is not sufficient shelf room to warrant the preparation of a new catalogue, and it is evident to all who visit the room that other and larger accommodations must be secured in the near future if our library is to be made serviceable to our members.

Through the efforts of the librarian four informal meetings have been held in the library on the Wednesday evenings not otherwise occupied with some regular Society event. The average attendance has been 20, and every one, apparently, has enjoyed the social element which has existed, besides in each case gaining valuable information on the matters under discussion.

These gatherings have been held with the idea of supplementing the work of

the regular meetings by giving to a comparatively small number of men an opportunity to study the details of various works much more clearly than would be possible during a formal discussion. Besides this the effect is to give to such members as attend a better acquaintance with the room and its opportunities.

An important feature of the meeting has been the lack of any attempt at formality. This gives the privilege of asking a question whenever it may occur to the questioner, thus bringing out many of the smaller points that would ordinarily be passed over.

While these meetings are undoubtedly interesting and instructive to the older members of our profession, the younger men in particular owe it to themselves to embrace all opportunities for broadening their observation on all of the various subjects under discussion, since it is to them that the close study of detail usually falls.

Copies of the various detail plans so far exhibited have been promised, but on account of lack of space no attempt has as yet been made to obtain them.

The report of the Treasurer shows a net increase of $581.54 in the funds in his hands.

Respectfully submitted on behalf of the Board of Government,

JOHN R. FREEMAN, *President.*

ABSTRACT OF THE TREASURER'S AND SECRETARY'S REPORTS FOR THE FINANCIAL YEAR 1893-94.

CURRENT FUND.

Receipts.

Dues of resident members for 1892-93, 2 @ $6	$12 00
" " " " 1893-94, 230 @ $6	1,380 00
" non-resident " " 1893-94, 58 @ $4	232 00
" " " " 1893-94, 2 @ $1	2 00
" " " " 1894-95	4 00
" resident " " 1894-95	7 00
" new members	103 00
Special assessments, 297 @ $1	297 00
Sales of Journals	4 50
Rent of office	175 00
Interest on deposits	10 88
Cash at beginning of year	64 74
	$2,292 12

Expenditures.

Association of Engineering Societies for Journal	$956 25
Rent	506 00
Secretary's salary	200 00
Printing, postage and stationery	219 80
Periodicals and binding	117 62
Expenses of meetings, stenographer and lantern	106 10
Annual dinner expenses	49 70
Gas	4 97
Cash on hand	131 68
	$2,292 12

PERMANENT FUND.

Receipts.

Twenty-four entrance fees	$240 00
Interest and dividends	173 05
Cash at beginning of year	915 00
	$1,328 05

Expenditures.

Dues on shares in Merchants' Co-operative Bank	$300 00
Mortgage on real estate	970 00
Examining and insuring title	30 50
Cash on hand	27 55
	$1,328 05

SCHEDULE OF FUNDS OF SOCIETY ON MARCH 19, 1894.

One Republican Valley Railroad bond (par value)	$600 00
Nine shares C., B. & Q. R. R. stock (par value)	900 00
Mortgages on real estate	1,800 00
Twenty-five shares Merchants' Co-operative Bank	1,771 85
Cash on hand, Permanent Fund	27 55
" " Current Fund	131 68
	$5,231 08
Schedule presented at last annual meeting	4,649 54
Increase during the year	$581 54

Report of the Committee on Excursions.

Boston, March 21, 1894.

To the Boston Society of Civil Engineers:

During the past year your committee has provided for the Society nine excursions, and although for seven years previous to last year a summer excursion, covering several days, has been arranged, it was thought best this year to omit this excursion, since so many of the members had planned to attend the World's Fair at different times.

The following is a list of the excursions made by the Society during the past year, with the approximate attendance:

April 19, 1893.—Boston Bridge Works, 30 present.

May 17, 1893.—General Electric Company, Lynn, 50 present.

June 21, 1893.—Experimental Station at Lawrence, and New Filter, 37 present.

September 20, 1893.—Metropolitan Sewerage Works, Deer Island, 65 present.

October 18, 1893.—Sewage Disposal Works, Brockton, 45 present.

November 15, 1893.—Boston Rubber Shoe Company, Malden, 30 present.

January 24, 1894.—New Public Library and Natural History Rooms, 35 present.

February 21, 1894 —State House Extension, 40 present.

March 21, 1894.—North Packing and Provision Company and New England Dressed Meat and Wool Company, Somerville, 19 present.

For the Committee,

F. V. Fuller, *Chairman.*

Report of Committee on the Library.

At the beginning of the year which now expires the library had just been removed to its present quarters in this building, and the books had been classified and arranged under the direction of Mr. Hodgdon.

In order to provide sufficient room for the new books which came from the binders and elsewhere in the early summer, all the books had to be re-arranged, keeping the classification practically the same, but putting in the background those books least likely to be required.

Just what can be done when last year's periodicals come back from the binders remains to be seen, as all the available space is now practically occupied.

The cases and the room are so crowded that one encounters more or less annoyance in trying to obtain information from the shelves. I sincerely hope that some means will appear by which to make the library more nearly what is necessary to make it of the greatest usefulness to this Society.

It was hoped that something could be done in the way of preparing a catalogue, which is much needed; but mainly on account of the large amount of labor involved, and partly on account of the great proportion of periodicals and reports, which rendered a subject index almost out of the question, nothing has been done about it.

The accession book shows that during the last year we have received some 300 books and pamphlets from various sources mainly by gift. There is now on the table of the reading room a representative display of about thirty of the leading technical publications of the day, the majority of which are obtained by exchange or gift, and one cannot fail to find something of value or interest to repay him for looking it over.

The files of these papers, many of which are complete, make a most valuable reference library.

An attempt has been made to procure full sets of the technical reports of the various municipalities hereabouts, so that the historical branches should be properly attended to. The results are so far quite satisfactory.

The *use* of the library, from being almost nothing, has steadily grown, and if we continue to use our present quarters or remove to better ones, it will, I believe, continue to grow and will become all that could be asked.

I wish I could make clear to the members, and especially to the younger members, like myself, the great value of our library to them if they should choose to use it.

I hold it to be every man's duty to inform himself as far as possible as to the methods of others, and our library will, if properly questioned, have something to teach upon any given subject.

I sincerely hope to see the usefulness of the room extended, and this can be greatly promoted by the occupancy of enlarged quarters, for we could then make the library the focus of facts regarding all works in New England, as well as a repository of general engineering information.

For the Committee on the Library.

H. F. Bryant, *Librarian.*

March 21, 1894.

Western Society of Engineers.

312TH MEETING, MARCH 7, 1894.—The 312th meeting was held at Parlor 44, Grand Pacific Hotel, Chicago, at 8 P.M., March 7, 1894. Forty-five members and guests present. In the absence of President Herr, Vice-President Mead took the chair and called the meeting to order.

The minutes of the previous meeting were approved.

The Secretary reported action of the Board of Directors as follows:

At the meeting of the Board held to-day, Mr. Arthur E. Rutledge, of Rockford, Ill., was elected to membership. The applications for membership of Messrs. A. W. Gates, of Aurora, Ill., and Alexander Von Babo, of Chicago, were received and placed on file.

Four delinquent members, having paid up all arrearages, were reinstated to active membership.

A letter from Mr. O. Chanute, Chairman of the General Committee of Engineering Societies, enclosing a dividend of $67 20, was received and placed on file.

A letter from Mr. Charles J. Roney, stating that on account of illness he had been unable to complete his proposed paper for this evening's meeting, was received, and it was ordered that the paper of Mr. C. H. Hudson, on the original construction of the Burlington bridge, be presented in lieu of the one heretofore announced.

The following resolution was passed:

Resolved, That no books, papers or periodicals belonging to the Society be taken from the rooms of the Society without permission of the Board of Directors.

A motion that the report of the Board of Directors be approved and filed was seconded and carried.

The report of the Secretary was then read, as follows:

Funds received since last meeting, $269.06, which amount has been turned over to the Treasurer.

Contributions to the library have been received from Messrs. Howard N. Elmer, Jacob Harman, James F. Lewis, George D. Stonestreet, and C. J. Roney.

A motion that the report of the Secretary be received and filed was seconded and carried.

The Treasurer reported funds on deposit March 1st, $853.15.

The report of the Treasurer was received and placed on file.

The report of the Committee on Memorial on Isaac Collins Chesbrough was read by the Secretary.

It was ordered that the report of the committee be accepted and printed, and that a copy of the memorial be sent to the family of the deceased.

The committee on reorganization reported progress, and the report was received and placed on file.

THE CHAIR: Since the last meeting of the Society we have met with a great loss in the death of our Ex-President, Mr. Abram Gottlieb, who died suddenly in this city on the 9th day of February.

It was ordered that the Chair appoint a committee of three to draw up a memorial of the deceased member. The Chair appointed Messrs. Morrison, Strobel and Hughes as such committee.

The Secretary then read a letter from Mr. Chanute, containing a translation of a letter of thanks from the German Society of Engineers to the various Engineering Societies which united in forming the General Association of Engineering

Societies and which maintained the Engineering Headquarters in this city during the World's Fair. The German Society expresses its appreciation of the arrangements made for foreign engineers, and expresses the hope that it may at some time be able to extend similar courtesies to the engineers of this country and that the interchange of ideas on scientific and engineering subjects may become even more active than it has been.

THE CHAIR: Executive Committee Circular No. 4, being the final report of the Executive Committee of Engineering Societies of the Columbian Exposition, has been received by the Secretary, and is on file at his office. The Committee so managed its trust as to be able to declare a dividend of ten per cent. upon closing its accounts.

Mr. Hudson's paper on the Original Construction of the Burlington Bridge was then read by the Secretary.

After discussion, participated in by Messrs. Morison, Goldmark and Appleton, the meeting adjourned.

THOMAS APPLETON, *Secretary.*

Engineers' Club of St. Louis.

395TH MEETING, MARCH 7, 1894.—The Club met at 1600 Lucas Place, at 8.15 P.M., President Crosby in the chair. Forty members and two visitors were present.

The minutes of the 394th meeting were read and approved.

The Executive Committee reported the doings of its 157th meeting.

An application for membership was announced from Edward B. Fay, civil engineer, with George S. Morison, Chicago.

The Secretary read the final report of the Executive Committee of the associated engineering societies having in hand the entertainment of the guests of the Columbian Exposition. There being a balance left over, the sum of $35.00 was returned to this Club. On motion, it was ordered that the Executive Committee place this sum to the credit of the library fund.

The American Society of Civil Engineers having presented the Club with certain volumes of its Proceedings which had been missing from the Club's files, a vote of thanks was extended to them.

It was on motion ordered that a committee of five be appointed by the Chair to devise means to raise funds, to consider questions relative to the improvement of the library, and to report back to the Club, the librarian to be a member of the committee. The Chair appointed on this committee Messrs. J. A. Laird, Philip N. Moore, T. L. Condron, J. B. Johnson and E. A. Hermann.

Mr. M. L. Holman, Water Commissioner of the city of St. Louis, then addressed the Club upon the general features of the New Water Works, discussing the matter briefly in its historical, present and future aspects. The first agitation for water works in St. Louis began in 1829, and the first works were built in 1833–36, with a pumping station at the foot of Ashley Street, and a wooden reservoir, 100 feet square, at Collins and Ashley Streets. The pipes were all of lead, and were put in by the city. The works were later removed to the foot of Bates Street, with a reservoir at Twenty-second and North Market Streets. Mr. Kirkwood, of Brooklyn, was appointed to make investigations for a new system, and, as a result, the present system at Bissell's Point was constructed, and went into service in 1872. There are now 420 miles of pipe in this city, the amount having doubled in the last

fifteen years. The general features of the new works at the Chain of Rocks and at Baden were described. The question, as to the best method of handling sediment in the Bissell's Point reservoirs, was discussed. The reservoirs being now operated at more than double their rated capacity, it was found necessary to operate them by continuous flow, which rendered it impossible to secure any great amount of settlement.

After discussion by Messrs. Moore, Flad, Seddon, Ferguson and Crosby, the meeting adjourned.

William H. Bryan, *Sec: etary.*

396th Meeting, March 21, 1894.—President Crosby called the Club to order at 8.30 p.m., at 1600 Lucas Place. Forty members and four visitors present.

The minutes of the 395th meeting were read and approved.

The Executive Committee reported the doings of its 158th and 159th meetings, recommending E. B. Fay for election to membership. He was balloted for and elected.

Applications for membership were announced from George Brenneke, assistant engineer, Bellefontaine Bridge, and Charles G. Mitchell, assistant engineer, Water Works Extension.

A letter of thanks was read by the Secrtary from the German Society of Civil Engineers, acknowledging courtesies extended by the Associated Engineering Societies during the Columbian Exposition.

Mr. S. Bent Russell then addressed the Club on the leading engineering features connected with the Water Works Extension, together with the organization and methods of the engineering force. Particular attention was paid to the question of determining the design of inlet tower, intake tunnel, engine house and conduit, and the methods employed in construction and the difficulties encountered, were described. The conduit is about 37,000 feet long. From the Chain of Rocks to Baden it is 11 feet in diameter, and is expected to deliver 100,000,000 gallons in twenty-four hours. From Baden to Bissell's Point it is 9 feet in diameter, and has a capacity of 65,000,000 gallons. These calculations are based upon a computed velocity of 2 feet per second. The address was illustrated by numerous lantern slides, showing the progress of the work. The hour being late, adjournment was had without discussion.

William H. Bryan, *Secretary.*

Civil Engineers' Club of Cleveland.

March 13, 1894.—Chamber of Commerce Rooms.—The meeting was called to order by the President at 7.50 p.m. Forty-one members and visitors were present.

The record of the meeting held on February 13th was read and approved.

An application for active membership was presented from Mr. James W. Morris, General Road Master, N. Y., L. E. & W. R. R., 30 Euclid Avenue.

A letter from Mr. O. Chanute was read, transmitting a translation of a letter from the Society of German Engineers, Berlin, to the General Committee of Associated Engineering Societies, expressing its appreciation of the courtesies extended to its members at the World's Fair. Another letter was read from Mr. Chanute, transmitting the final report of the General Committee of Engineering Societies,

Columbian Exposition, and returning $32 as the Club's share of the unexpended balance on hand after paying all bills.

The annual reports of the Secretary and Treasurer were read and accepted, and were ordered spread on the records.

A report from the Program Committee was read by Mr. George E. Gifford, Chairman, and one on the subject of "Architecture," by Mr. C. W. Hopkinson. These reports were accepted and on motion referred to the Library Committee for publication.

A report from the Local Committee on Columbian Exposition was presented by Mr. W. H. Searles, Secretary, and was received, adopted and ordered spread upon the records.

A report from the Committee on National Public Works was made to the effect that the committee at this time could do nothing further, and therefore asked to be discharged. The report was accepted and the committee discharged.

A report was received from the Committee on "New Quarters," through Mr. C. W. Wason, stating that the needs of the Club were being considered in the proposed remodeling of the Case Library building, and asking also that the committee be discharged. The report was accepted and the committee discharged.

Proposed amendments to the constitution in reference to canvas of votes for members and in reference to the method of nominating officers were presented by Messrs. James Ritchie, William T. Blunt and Frank C. Osborn. It was moved and carried that these amendments be laid on the table for one month. It was also moved and carried that the Secretary have the proposed amendments printed and mailed to the members with notices of the next meeting.

Mr. C. H. Benjamin announced that it is proposed to so arrange the contents of the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES that the proceedings can be separated from the papers in binding, if desired, and that by this arrangement space will be provided for short notices of general engineering interest. It is desired by the editor of the JOURNAL that members of the associated societies should forward to him for this purpose such notices as would be of value to the readers of the JOURNAL.

President A. H. Porter read the annual address, entitled "The Engineer and His Work."

The tellers submitted the following report of the result of the election of officers and members:

	For President.		
Ambrose Swasey	60	C. S. Howe	19
	For Vice-President.		
John N. Richardson	54	F. A. Coburn	25
	For Secretary.		
F. C. Osborn	60	F. H. Neff	19
	For Treasurer.		
C. P. Leland	56	J. C. Wallace	23
	For Librarian.		
C. H. Benjamin	52	A. H. Porter	27
	For First Director.		
C. W. Wason	44	C. F. Lewis	35
	For Second Director.		
N. B. Wood	39	Walter Miller	39
	For Members.		
Henry Earle Riggs, Corresponding	73	Isaac Knapp Pierson, Active	72
Edwin Grant Lane, Active	73	Charles Frederic Mabery, Active	73

Both candidates for Second Director having received the same number of votes, it was necessary to have another ballot. This resulted in 20 votes for Mr. Walter Miller, and 16 for Mr. N. B. Wood. Mr. Walter Miller was, therefore, declared elected to the office of Second Director.

Mr. C. P. Leland, Chairman of the Banquet Committee, announced that tho banquet would be held on Wednesday evening, March 21st, at the Hollenden Hotel.

The retiring President extended his thanks to the officers and members of the Club for the cordial support and co-operation given him during his administration, and particularly to Mr. W. H. Searles, for advice and assistance rendered.

On motion of Mr. W. R. Warner, a vote of thanks was unanimously tendered to the retiring officers for their labors and devotion to the interest of the Club during the year.

The meeting adjourned at 10 P.M.

FRANK C. OSBORN, *Secretary.*

Association of Engineering Societies.

PROCEEDINGS.

Western Society of Engineers.

313th Meeting, April 4, 1894.—The meeting was held at Parlor 1, Grand Pacific Hotel, Chicago, at 8 p.m. Thirty-six members and guests present. President Herr took the chair and called the meeting to order.

The minutes of the previous meeting were approved.

The Secretary reported action of the Board of Directors as follows:

At the meeting of the Board of Directors held March 26th, bills amounting to $357.45 were approved and ordered paid. This amount includes the bill for the Journal for the quarter ending March 31, 1894, which is $339.00. The Board authorized a renewal of the lease of the room, 51 Lakeside Building, for a term of one year from May 1, 1894.

At the meeting of the Board held April 4th, bills amounting to $137.20 were approved and ordered paid. The dividend received from the General Committee of Engineering Societies was appropriated for the purpose of sending forty copies of the proceedings of Division E. (Engineering Education) of the Congress, to a like number of Foreign Engineering Societies with the compliments of the Western Society of Engineers.

Messrs. Alexander W. Gates, of Aurora, Ill., and Alex. von Babo, of Chicago, were elected to membership.

The applications for membership of Messrs. Dion Geraldine, of Chicago, and Jacob B. Rohrer, of Lemont, Ill., were received and placed on file.

Funds amounting to $237.20 have been received since the last meeting of the Society and deposited with the Treasurer.

The Treasurer reports cash on hand March 31st, $514.42.

The report of the Board of Directors was read and received and ordered to be placed on file.

The Librarian then reported contributions to the library from Mr. F. A. Calkins, from Mr. T. J. Nichol, from Mr. Charles L. Strobel and from the library of the late William Scherzer.

The report of the Librarian was received and ordered to be placed on file.

The Secretary then read the report of the Committee on Memorial of William Scherzer, which will be printed in the Journal of the Association of Engineering Societies.

It was moved by Mr. Randolph that the report be received and placed on file

and printed in the JOURNAL, also that a copy of the memorial be sent to the family of the deceased. Seconded and carried.

The Committee on Reorganization reported progress.

After discussion it was unanimously ordered that the report be received and placed on file, and that the recommendations contained therein be approved and carried out.

THE PRESIDENT: The next and most interesting feature will be the reading of a paper by Mr. Charles J. Roney, entitled, "Some Notes on the German Collective Exhibit of Engineering at the World's Columbian Exposition."

Mr. Roney then read the paper, of which the following is a brief abstract:

The Royal Prussian Ministry of Public Works, of Berlin, made very extensive exhibit of plans, drawings, photographs and publications of the regulation of the Prussian rivers, construction of canals and improvements of harbors, etc., together with several models of movable river weirs.

There was also exhibited a self-registering river and tide gage of the Seibt-Fuess system, invented by Prof. Seibt, of Berlin, and constructed by R. Fuess, of Berlin.

Mr. F. H. Schmidt, of Altona Rainweg, exhibited two colored drawings and a sheet-iron model of his patent iron sheet piling with concrete filling, adopted for quay walls in Bremen, Vegesack and Cameroon.

Messrs. Menck & Hambrock, Altona, Hamburg, exhibited colored drawings of contractors' machinery for pier building at Santos Harbor, Brazil, consisting of steam pile drivers, a centrifugal pump for dredging mud, and a traveling crane for depositing concrete beton under water.

The city government of Worms exhibited a model of caisson used in Fischer's system of pipe laying in water-bearing earth, with colored drawings and photographs of the apparatus as used in laying the water supply pipes of the city of Worms on the Rhine.

The same city exhibited Fischer & Peters' plate filter system now in use in the water works of the city of Worms.

The Magistrate of the city of Frankfort-on-the-Main exhibited a collection of maps and colored drawings of the drainage and water supply system of that city, including precipitation and disinfection of sewage, details of pumping stations, wells, etc.

Mr. G. Luther, of Brunswick, exhibited a large number of drawings and photographs of machinery manufactured and works constructed by him. Among these were large duplex pumping engines, floating harbor cranes, the harbor installation of La Platta, Argentine Republic, etc.; also large water-color views and photographs of the improvement of the lower Danube, and colored drawings of the grain elevators of Galatz and Braila on the Danube. He also exhibited drawings of a project for the improvement of the harbor of Odessa, Russia, the principal shipping point for the great grain-producing region of Southern Russia. The estimated cost of the entire plant is upwards of $6,000,000.

Among the recent additions to the Society library are copies in German and French of a quarto publication by Mr. G. Luther, of 130 pages, very fully illustrated, to which reference is made for a full description and discussion of this project. Notes which had been prepared of many other interesting exhibits were not read for lack of time.

The writer expressed his warm appreciation of the entire German Engineering Exhibit; an exhibit which won the admiration alike of engineers, the press,

and intelligent visitors generally, and which is to be again exhibited during the coming summer in Berlin.

The President: Gentlemen, you have heard the results of an immense amount of labor. Undoubtedly Mr. Roney has touched upon some subject that is interesting to each one of you. Some of those descriptions may have brought up ideas that you have been working on, and you may get more information by discussing them. There is a great deal to be learned from German engineering, and perhaps more in the direction of hydraulic engineering, river work, etc., than in any other. I was particularly interested in that branch of the subject.

After remarks by Mr. Kandeler and others the meeting adjourned.

Thos. Appleton, *Secretary.*

Civil Engineers' Club of Cleveland.

Chamber of Commerce Rooms, April 11, 1894.—The Club met at 7.45, President Swasey and 35 members present. President Swasey made some opening remarks introductory to his term of office and recommended that the Club make excursions to manufacturing establishments during the year.

In the absence of the Secretary, Mr. Osborn, Mr. Wm. H. Searles was made Secretary *pro tem.*

The minutes of the March meeting were read and approved.

Mr. Palmer and Mr. Paine were appointed tellers for the evening.

A letter from Mr. Wason, President of the Electrical Club, was read, inviting the Civil Engineers' Club to visit one of the power stations on May 2d. On motion, the invitation was accepted with thanks.

Mr. Leland presented a report of the Banquet Committee, which was accepted and ordered placed on the minutes. The report was as follows:

Civil Engineers' Club 14th Annual Banquet, March 21, 1894.

Receipts. 146 Tickets, at $2.00	$292 00
Disbursements	$292 00

No surplus, no deficit; and hence, no assessment.

C. P. Leland, *Chairman.*

The proposed amendments to the Constitution were then taken up for discussion. Under Art. III, Mr. Searles moved that Sec. 6 of the proposed amendment be altered so as to read "The tellers shall use a tally sheet of the form given in the appendix (Form E)," and to strike out the numbered paragraphs in Sec. 6, the rest of the section to stand as given in the amendment.

Dr. Howe moved that Mr. Searles be requested to prepare the form "E" and submit it with the amendment for letter ballot. Seconded and carried.

In considering Art. VII, Mr. Thompson offered a written substitute for Sec. 1, which, after some discussion, was laid upon the table.

Mr. Searles moved to substitute, for Sec. 1 of the proposed amendment, the present Sec. 1, Art. VII of the Constitution, amended so as to read "This committee shall nominate one active member, etc.," instead of two active members as at present. This was seconded and adopted.

The tellers reported the election to Active membership of Jas. W. Morris.

Prof. Benjamin made some remarks upon the new issue of the JOURNAL, and urged members to furnish short paragraphs on engineering subjects which might be published in it. He also called attention to "Weston's Index of Current Engineering Literature," recommending its purchase by the members as a work of great value.

Mr. Porter recommended that the Club have a committee on rooms, and on motion the committee of last year was reappointed, consisting of Messrs. Wason, Porter and Langley.

The President announced the death of two members of the Club, L. L. Leggett on April 2d and C. B. Krause on April 3d. On motion, two committees were appointed by the President to prepare memorials of the lives of these deceased members. In relation to Mr. Leggett, the committee is composed of Messrs. Leland, Morley and Warner. In relation to Mr. Krause, the committee is composed of Messrs. Alex. E. Brown, Osborn and Richardson.

The President announced the committees for the year. On *Finance*, Jno. N. Richardson, C. P. Leland and C. W. Wason; *Library*, C. H. Benjamin, F. C. Osborn and Walter Miller; *Programme*, Geo. Bartol, A. E. Brown, E. C. Cooke, W. C. Jewett, J. W. Langley, W. W. Sabin and Jared A. Smith.

The paper of the evening was read by Mr. West, entitled "A Plea and Plan for Suburban Homes and Rapid Transit for City Employés," and was discussed by Messrs. Porter, Howe, Thompson, and others.

The hour being late, the second paper announced for the evening was postponed, and at 10 o'clock the Club adjourned.

W. H. SEARLES, *Secretary pro tem.*

Engineers' Club of St. Louis.

397TH MEETING, APRIL 11, 1894.—President Crosby called the Club to order at 8.30 P.M. at 1600 Lucas Place. Thirty-two members and three visitors present.

In the absence of the Secretary, Mr. T. L. Condron was appointed Secretary *pro tem.*

The minutes of the 396th meeting were read and approved.

The Executive Committee reported the doings of its 160th meeting, approving the applications for membership of Messrs. Chas. Dwight Mitchell and Wm. George Brenneke. They were unanimously elected to membership, twenty-nine votes being cast.

Applications for membership were announced from Guy Willis Latta, engineer with Chas. W. Melcher Machinery Company, and Prof. Wm. Kendrick Hatt, Associate Professor Civil Engineering, Purdue University.

The committee appointed at the 395th meeting to devise means for improving the library, submitted the following report:

Members Engineers' Club of St. Louis.

GENTLEMEN: Your Library Committee met on April 4th, at 4 P.M. in the Club rooms.

The chairman read several communications from publishers of engineering journals regarding rates of subscriptions and price for back volumes.

The committee does not favor the purchase of back volumes from the publishers, but would recommend, when the Club has sufficient funds to apply to this purpose, to advertise for all back numbers desired.

The committee further recommends subscribing for the *Engineering News* and *Railroad Gazette* immediately; also the purchase of Howe's book on steel.

The committee further recommends the creation of a fund of $150, to be expended each year for five years; and suggests that fifty or more members of the Club guarantee to contribute $3 per year for five years, or such part of that amount as would bring the sum contributed by the Club for library purposes up to $150 each year.

Respectfully submitted,

JOHN A. LAIRD.
J. B. JOHNSON.
E. A. HERMANN
PHILIP N. MOORE,
T. L. CONDRON,
Committee on Improvement of Library.

On the motion of Mr. Russell, seconded by Mr. Colby, the report was adopted.

On the motion of Mr. Perkins, seconded by Mr. Russell, the committee was made a permanent one to continue the work of improving the library.

The librarian announced the presentation of a copy of the "Personal Recollections of Werner Von Siemens" to the library by Mr. E. F. Leonard, and moved a vote of thanks of the Club be extended Mr. Leonard. Seconded by Mr. Flad. The Club voted the same unanimously.

The paper of the evening was then presented by Mr. J. A. Laird, mechanical engineer of the water works extension, upon the "New Machinery now Being Installed." Mr. Laird gave a general description of the four different types of pumping engines under contract, with cost of each. The main shaft of high service engine No. 6 is of nickel steel, 92,000 pounds tenstile strength and 22 per cent. elongation in four diameters. The capacity and duty tests on Chain of Rocks engines are to be for 720 consecutive hours. There is a 15-ton electric traveling crane in the engine house at the Chain of Rocks; vertical hoist, 80 feet. It has not caused a moment's delay in nine months' use, and is looked after and run by an ordinary helper.

There are separate steam mains for each pair of engines. All feed water will be metered. The running of the entire plant will be made as near as possible a perpetual duty trial.

The specifications for the Baden 10,000,000-gallon engines call for 125,000,000 foot-pounds duty, and offer a bonus of $1,000 per million of duty developed above 125,000,000; and provide a forfeit of $2,500 per each million that the duty falls below 125,000,000.

These engines are provided with pressure relief valves, capable of by-passing all water delivered back into suction.

The Baden engine house will be provided with a 20-ton electric traveling crane.

When the stations at Baden and Chain of Rocks are completed, the engines and boilers will be put on regular running watches, and will be overhauled at regular intervals. It is expected that the new machinery will be able to do the same work at half the cost of the present plants, and save, on a 15,000,000 gallon high-service engine running two-thirds of the time, $7,150 per year, which is 5 per cent. interest on $143,000.

The discussion was opened by Mr. Flad and continued by Messrs. Seddon and Ferguson and Prof. Kineally.

A number of fine lantern slides were thrown upon the screen illustrating the extension of the water-works. Adjourned.

T. L. CONDRON, *Secretary pro tem.*

398TH MEETING, APRIL 18, 1894.—The Club was called to order at 8.30 P.M. by Vice-President Russell at 1600 Lucas Place. Thirty-five members and ten visitors present.

The minutes of the 397th meeting were read and approved.

The Executive Committee reported the doings of its 161st meeting, announcing the resignation of H. S. Pritchett, to take effect June 1st, and approving applications for membership from W. K. Hatt and G. W. Latta. They were balloted for and elected. An application for membership from E. P. Fredericks, superintendent of Broderick & Bascom Wire Rope Company, was announced.

The Secretary read the following:

President Engineers' Club, City.

DEAR SIR: As chairman of the committee appointed by the Engineers' Club of St. Louis for the purpose of inaugurating the movement to establish boulevards, I wish to report that, under instructions from the Club of February 22, 1894, your committee has co-operated with the committee appointed by the Society of Architects, and the joint committee has concluded to organize a committee of sixty to inaugurate the movement.

Communications were addressed by the joint committee to the different clubs and exchanges in the city, and in consequence thereof the following gentlemen have been selected to co-operate with us, to-wit:

Real Estate Exchange—Jas. M. Carpenter, Leslie A. Moffitt, Jno. H. Terry, Ed. B. Wolff and A. O. Rule.

Mercantile Club—Frank Gaiennie, F. A. Drew, C. C. Nicholls, J. M. Jordan and J. B. Case.

Builders' Exchange—Anthony Ittner, Jas. D. Fitzgibbon, Daniel Evans, Wm. J. Baker, Wm. A. Rutler and Jere Sheehan.

University Club—E. B. Adams, E. C. Dameron, Walker Hill and H. T. Kent.

Merchants' Exchange—D. R. Francis, Chas. Parsons, Geo. H. Small, Jno. W. Kauffman and F. N. Judson.

St. Louis Club—H. Clay Pierce, S. M. Dodd, O. L. Whitelaw, Ellis Wainwright and Clinton Rowell.

Union Club—Maj. C. C. Rainwater, E. T. Allen, H. A. Haeussler, E. S. Rowse and Jas. Christopher.

Commercial Club—E. O. Stanard, Jno. S. Moffitt, Alvah Mansur, I. M. Morton and Geo. H. Holland.

Architects' Club—Wm. S. Eames, R. W. Walsh, Fred Widmann, Craig McClure and Chas. K. Ramsey.

Engineers' Club—Prof. C. M. Woodward, Prof. W. S. Chaplin, Prof. W. B. Potter, Robt. Moore and Julius Pitzman.

At the meeting held at the Mercantile Club, April 11th, it was resolved to appoint an executive committee of thirteen to submit a plan of organization at the next meeting, and said committee was also authorized to select ten additional members for the committee in compliance with the request of the joint Committee of Architects and Engineers. In the course of the next week we expect to complete the organization.

A committee, consisting of Messrs. Woodward, Eames and myself, was appointed to call on the Mayor with reference to the matter, and we were assured by the Mayor and by the members of the Board of Public Improvements who were present at the meeting, by request of the Mayor, that the administration was in harmony with the movement and would assist in any systematic movement. Very respectfully,

JULIUS PITZMAN, *Chairman of Committee.*

Mr. R. E. McMath then delivered the fourth of the series of addresses on the "New Water Works," having special reference to the quality of the water supply. He showed that the location of intake at the Chain of Rocks was the best that could be selected, as it permitted of an extension by tunnel 4½ miles long, to Bellefontaine Bluffs on the Missouri River, should such an extension ever prove desirable. The location of the high-service stations at Bissell's Point and Baden was also shown to be admirable for the purpose. The general scheme of handling and distribution was explained. He showed that it was quite possible for Mississippi River water to reach the intake, but denied that this water was worse than Missouri River water. He showed the extent of pollution from Chicago sewage now existing, and the amount to be expected when the drainage canal is put into service.

He called attention to the lack of value of analysis and other investigations of water supplies made heretofore, and urged an investigation of the entire subject by the general government as being free from all suspicion of local or other prejudicial influences.

The discussion was very full, and was participated in by Messrs. Ockerson, Holman, Johnson, Ferguson, Macklind, Kineally, Seddon and Flad.

The following visitors also added materially to the interest of the discussion: Prof. Sanger, Drs. Green and Ravold and Mr. Wixford. Adjourned.

WM. H. BRYAN, *Secretary.*

Montana Society of Civil Engineers.

APRIL 14, 1894.—The regular monthly meeting was called to order by President W. A. Haven; six members being present.

The minutes of meetings held February 10th and March 10th, were read and approved.

The Secretary read a communication from Mr. O. Chanute, transmitting the final report of the Executive Committee of Engineering Societies, and returning $12.00 to the Society, its share of the balance remaining on hand from the amount contributed by the different societies for the entertainment of visiting engineers at the World's Columbian Exposition; also a letter from the Board of the Society of German Engineers to the General Committee of American Engineering Societies, extending the thanks of that Society for the entertainment of its members at Chicago.

A letter was read from Mr. Joseph H. Harper relative to the measurement of water under the Montana statute defining a miner's inch, in which Mr. Harper stated that it had been his practice to use one and a half cubic feet per minute as being a very close approximation to the old miner's inch.

He believed the present law was ambiguous and self-contradictory, and doubted if it would be possible to frame any law for the measurement of a miner's inch, that would be uniformly construed in the same manner by the courts and the various engineers who would be called upon to interpret it.

A letter was read from the Hon. E. J. Hainer, member of Congress from Nebraska, relative to the bill regulating postal rates on Society publications, in which Mr. Hainer stated that a suitable amendment would be offered to the pending bill providing for the admission of all scientific and professional publications to the U. S. mails as second-class matter.

The question of ownership of an engineer's notes was quite thoroughly discussed.

Mr. Cumming stated that in this State an engineer is often called upon to run some important connection line in a mine, and the execution of the work after it is laid out devolves upon the mine superintendent or foreman. If he should fail to follow the engineer's lines and instructions, the work, when completed, might not connect, and the engineer would be liable for an action for damages. If he had parted with his original notes he would have nothing to show that his work had been correctly done and where the fault really lay. The mining company should, however, be furnished with a full and complete copy of all the notes as soon as the survey is made.

Other instances were cited where an engineer would be justified in retaining either a copy or the original notes.

The opinion of most of those present was that the employer is entitled to all notes and information obtained from any survey, but that the engineer making the survey ought to have the right to retain either the original notes or a copy of the same whenever he considers them of importance for future use; provided they are not to be used to the detriment of his employer's interests.

No further business offering, the Society thereupon adjourned.

G. O. Foss, *Secretary.*

Boston Society of Civil Engineers.

April 18, 1894.—A regular meeting of the Society was held in its rooms, 36 Bromfield Street, Boston, at 7.55 o'clock p.m. Seventy-eight members and visitors were present.

President William E. McClintock, in calling the meeting to order, thanked the members for the honor they had conferred upon him in electing him to preside during the coming year, and promised to serve them to the best of his ability.

The record of the last meeting was read and approved.

Messrs. William T. Barnes, Sumner Hollingsworth and William F. Williams were elected members of the Society.

The following by-law, proposed by the Board of Government at the last meeting, was adopted unanimously:

"Any member of any other Society in the Association of Engineering Societies, in good standing, may become a member of this Society, when duly elected as described in By-Law 7, without paying the entrance fee, and with a release from the annual dues for such period, not over one year, as he may show by certificate he has paid in advance in the Society from which he comes."

The Board of Government reported that it had appointed the following special committees:

On Excursions—F. I. Winslow, C. T. Main, F. C. Coffin, H. B. Wood and H. S. French.

On Permanent Quarters—Thomas Doane, Desmond Fitz Gerald, E. W. Howe, M. M. Tidd and C. F. Allen.

On the Library—H. F. Bryant, S. E. Tinkham, H. D. Woods, J. H. Stanwood and F. E. Sherry.

Board of Managers—S. E. Tinkham, John R. Freeman and Henry Manley.

The Board of Government recommended that the sum of $75 be appropriated for binding and other library purposes, and on motion the recommendation was adopted.

Prof. A. E. Burton, for the Committee on Weights and Measures, submitted and read its annual report. On motion the report was accepted and ordered printed.

On motion the Committee on Weights and Measures, as at present constituted, was continued until the next annual meeting.

Mr. William B. Fuller read a paper on Street Grades and Intersections, which was discussed by Messrs. Manley and Brooks and others.

Mr. Arthur L. Plimpton then gave a very interesting account of the experience of the West End Street Railway Company, in welding its tracks electrically. Mr. Plimpton's remarks were illustrated by blackboard sketches and specimens of the rails as welded.

Adjourned.

S. E. Tinkham, *Secretary.*

Report of the Committee on Weights and Measures.

Submitted April 18, 1894.

In the report of the Committee on Weights and Measures presented last year the stand was taken that this committee could best fulfill its duty to the Society, not by advocating any particular system of units of measure, not by urging any present action in this matter, but by presenting simply a condensed record of contemporary events transpiring in the world-at-large with reference to the simplification and perfection of standards of measure.

The present committee has decided in the main to follow the same plan, and begs leave to submit, as matters of interest to all who desire to see progress in the art of measuring, the following facts.

During the past year the Commissioners of the Topographical Survey of Massachusetts have completed the work of accurately locating all the town boundary monuments in 23 towns in the southeastern portion of the State. This work has been carried on with a singleness of purpose to accomplish the best results which should commend it to all who are interested in precision and accuracy of statement. Every well-authenticated town boundary monument has been located with reference to its latitude and longitude, and by its distance and direction from adjoining monuments, with an error of location which rarely exceeds the size of the horizontal surface of the monument itself. The records of the town boundary work are accessible to all engineers and surveyors, every town having a manuscript record of the latitude and longitude of each monument, of the distances between monuments in meters and in feet, and of the true bearing or azimuth from one monument to another, together with such a description by plot and perspective sketch that the monument may readily be found. In addition to the above data the commissioners are including in their triangulation nearly every church-spire or other suitable permanent signal, and the relative positions of these points are to be given with reference to each other in a manner similar to that pursued with town boundary monuments. Every individual surveyor is thus furnished with a general triangulation system on which he can readily base any detailed map.

The above matter has seemed pertinent material for this report, inasmuch as this work tends to foster respect for accurate measurements with uniform standards.

Between June and November of 1893 a line of precise levels was run between tide-water at Boston and previously established bench-marks at Albany, N. Y. The location of this line, which furnishes an axial line of geodetic levels to which all vertical measurements can be confidently referred, was part of the work under the charge of the Commissioners of the Topographical Survey. Bench-marks, accurately described, are given at intervals along the entire line.

The portion of this work which appeals to this committee is: First, the establishment of a uniform datum plane for levels across the State, namely, mean tide water; and, secondly, the high degree of precision attained in the measurement, which corresponds to that of the best geodetic leveling in the world. The checking of this line at Springfield with the line of levels run from mean tide at Hartford by General Ellis of the U. S. Engineers, gives some idea of the accuracy attained, the difference between the two lines being but one-tenth of a foot, which of course includes any error in the determination of mean tide level at Hartford.

During the past five years an increased interest in the determination of the value of the force of gravity and from this the figure of the earth, has been

awakened in this country by the invention and use of a new form of half-second pendulum, by means of which the differential value of gravity can be determined with an accuracy heretofore unknown in this country. In March, 1894, a determination of the value of gravity was made with this new apparatus by a Coast Survey Party at the Cambridge Observatory, and in the basement of the new State House Extension. The value of *g*, determined by these experiments, is the most reliable that has been given us by local physicists.

In connection with these accurate determinations of standards, the work of Prof. Michaelson of Clark University and of Dr. Gould of Cambridge, should perhaps be placed first, although it bears but somewhat indirectly upon engineering work. The paper read before the American Metrological Society in New York on March 31, 1894, gave the latest account of these experiments to determine the length of the meter in terms of wave lengths of light.

In July, 1893, in a paper read before the American Society of Civil Engineers, in Chicago, Prof. T. C. Mendenhall, Superintendent of the U. S. Coast and Geodetic Survey, and Superintendent of the U. S. Weights and Measures, announced the official adoption of the international metric standards as the fundamental standards of all measures in the United States. In other words, if the length of our yard is desired, it must be determined by reference to the international prototype meter; and our measures of capacity and of weight must be referred to the liter and kilogram respectively; this being at present the only possible way of stating these measures with accuracy. This adoption received the signature of Secretary Carlisle, April 5, 1893.

In July, 1893, the Engineering Congress at Chicago passed the following vote: "That a uniform system of testing materials is desirable for purposes of exact comparison." This certainly points to the fact that in international testing only those measures should be used that can properly be called international, namely, those of the metric system.

In August, 1893, at the World's Congress of Electricians, there was adopted a report by the Chamber of Delegates, recommending a system of international units including the "Henry," named after Prof. Henry, and based upon metric standards.

Recent statistics of the U. S. Custom House show that a very large portion of our foreign commerce is now transacted with countries using metric units, and renewed efforts are therefore being made in many quarters, to bring about the exclusive use of the metric system in our customs service. Petitions urging action in this direction are now being sent to Congress.

The last edition of the *Pharmacopœia*, issued in the fall of 1893, uses the metric units in stating capacities and weights.

In England the organization known as the New Decimal Association is displaying marked activity; and a prominent English house, that of Messrs. Willians & Robinson, of Thames Ditton, Surrey, has just adopted the use of metric measures throughout its works.

In countries which have already adopted the meter, there appears to be no tendency towards a change of standards.

The committee wishes to call the attention of the society to the following act, just approved by our state legislature:

COMMONWEALTH OF MASSACHUSETTTS.

CHAPTER 198.

AN ACT to establish a law uniform with the laws of other States for a uniform standard of weights and measuses.

Be it enacted, etc., as follows:—

SECTION 1. The avoirdupois pound shall bear to the troy pound the relation of seven thousand to five thousand seven hundred and sixty. The hundredweight shall contain one hundred avoirdupois pounds, and the ton twenty hundredweight.

SEC. 2. The barrel shall contain thirty-one and one half gallons, and the hogshead two barrels.

SEC. 3. *The dry gallon shall contain two hundred and eighty-two cubic inches;* and the liquid gallon two hundred and thirty-one cubic inches.

SEC. 4. *The bushel in heap measure shall contain twenty-one hundred and fifty and forty-two one hundredths cubic inches.*

SEC. 5. The barrel of flour, measured by weight, shall contain one hundred and ninety-six pounds; and the barrel of potatoes, one hundred and seventy-two pounds.

SEC. 6. The bushel of wheat shall contain sixty pounds.

The bushel of Indian corn, or of rye, fifty-six pounds.

The bushel of barley, forty-eight pounds.

The bushel of oats, thirty-two pounds.

The bushel of corn meal, fifty pounds.

The bushel of rye meal, fifty pounds.

The bushel of peas, sixty pounds.

The bushel of potatoes, sixty pounds.

The bushel of apples, forty-eight pounds.

The bushel of carrots, fifty pounds.

The bushel of onions, fifty-seven pounds.

The bushel of clover seed, sixty pounds.

The bushel of herdsgrass, or timothy seed, forty-five pounds.

The bushel of bran and shorts, twenty pounds.

The bushel of flaxseed, fifty-five pounds.

The bushel of coarse salt, seventy pounds.

The bushel of fine salt, fifty pounds.

The bushel of lime, seventy pounds.

The bushel of sweet potatoes, fifty-four pounds.

The bushel of beans, sixty pounds.

The bushel of dried apples, twenty-five pounds.

The bushel of dried peaches, thirty-three pounds.

The bushel of rough rice, forty-five pounds.

The bushel of upland cotton seed, thirty pounds.

The bushel of sea island cotton seed, forty-four pounds, and

The bushel of buckwheat, forty-eight pounds.

Approved, April 5, 1894.

Sections 3 and 4 establish a dry gallon and bushel which do not correspond with those previously recognized as United States measures. The minute specification of the weight of a bushel of different substances is not at all complete, and might be easily made to give contradictory values. The kind of pound is not specified, and the value of the peck and of the quart are left to speculation. The

law has been framed in a most hap-hazard fashion, and it may lead to complications and fraud.

In conclusion, we beg to report, that, although we do not suggest any movement on the part of the Society at the present time, with reference to the metric question, they cannot but see that the events of the day point to the conclusion that the meter is now established in our midst, and that it is only a question of a comparatively short time when its use will have become general, whether we wish it or not.

Alfred E. Burton,
Laurence Bradford,
Arthur C. Walworth, *Committee.*

Association of Engineering Societies.

PROCEEDINGS.

Montana Society of Civil Engineers.

May 12th, 1894.—Regular monthly meeting held.

The meeting was called to order by President Haven. Seven members and two visitors were present.

The minutes of the meeting held April 14th were read and approved.

The Secretary was instructed to notify the committee on the DeLacy memorial to report at the next meeting.

A communication was read from Prof. J. B. Johnson, relative to the postal rates on society publications.

Mr. Geo. Scheetz was appointed to furnish the Society with a paper for the June meeting, and Mr. Walter S. Kelley for the July meeting.

The Society then proceeded to the discussion of the law regulating the appropriation of water.

Mr. Foss read the Montana law and suggested improvements in line with the laws of Colorado and Wyoming, extracts from which were read.

After further discussion, Mr. Keerl offered a resolution that a committee of five members be appointed to consider the subject of the appropriation and use of water, and to suggest such changes in the present law as they deemed advisable with a view of advancing the interests of irrigation in Montana.

The chair appointed as such committee: Messrs. Keerl and Foss of Helena, Harper of Butte, Ryon of Bozeman, and Scheetz of Miles City.

The Secretary was instructed to correspond with the Butte members with a view of holding the July or August meeting of the Society in that city.

No further business offering, the Society adjourned.

G. O. Foss, *Secretary.*

Civil Engineers' Society of St. Paul.

Monday, May 7, 1894.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8 p.m. Thirteen members and six visitors were present. The minutes of the previous meeting were approved.

Mr. O. Claussen read the paper of the evening, on the "Requirements of a Municipal Electric Light-Plant Installation." He advocated the location of the

power-house near a plentiful supply of water, in order that compound condensing-engines might be used, yet far enough from the business center, to escape excessive cost of real estate, and near enough to profit by transportation facilities, and to minimize the length of pole lines. Tiled floors for engine and dynamo rooms were suggested, rubber mats to be placed where necessary for protective insulation. A traveling crane would assist in handling equipment. Machinery foundations should be massive, and built of hard-burned brick laid in Portland cement. The paper favored low-speed, triple-expansion engines, water-tube boilers, extra feed-pump capacity, economizers, and smoke-consumers; steam-pipes to be furnished with magnesia casing, and fitted with numerous valves, in case of accidents. For arc-lighting, the general practice seems to demand shafting and belt connections, while direct connection between engine and dynamo is common for incandescent lighting. The direct constant-current arc-light machine is now constructed to operate in safe practice one hundred 2,000-candle-power lamps, with a voltage of 5,000 and a current of 10 amperes. In this vicinity, with a first-class plant, a system of 1,000 lamps should be operated all night, and every night, at a total cost of $90.00 per lamp per annum.

C. L. ANNAN, *Secretary.*

Civil Engineers' Club of Cleveland.

CHAMBER OF COMMERCE ROOMS, MAY 8, 1894. — The meeting was called to order by the President at 7.50 P.M. Forty-seven members and visitors were present.

The record of the meeting held on April 11th was read and approved.

Applications for active membership from Messrs. N. S. Crouch and W. S. Thompson were read.

A letter of thanks from the Secretary of the English Society of Engineers, for services rendered foreign engineers during the World's Columbian Exposition, was read.

Prof. E. W. Morley presented the following resolution: *Resolved*, That in the death of Leverett L. Leggett our Club has lost a most valued member, and this city a most estimable citizen.

Dr. Leggett, in his intense and absorbing zeal in the duties and aspirations of life, did the work of two or three men, and so was stricken down suddenly, a comparatively young man, with his reserve of youth and vigor so overdrawn that there was no basis for a rally when the fatal stroke came like a flash of lightning. Only a miracle could have prevented it.

Dr. Leggett became a member of this Club, April 2, 1880, at the first meeting after its organization. He seldom, if ever, met with us, for he was too fully occupied. In fact, he was in Cleveland but little of late years, although his attractive home, where he was fairly idolized, was here. Hotels, sleeping cars and court rooms, widely separated, formed his unattractive environment; but he never faltered at the call for defense of the great legal interests intrusted to him.

Of most engaging personality, of happy, cheerful temperament, and gifted far beyond others, he reminded one of a diamond with many facets. There seemed to be nothing which his active, brilliant brain could not conquer. He was first a physician and then an able patent lawyer. He was a musician, an astronomer and an all-around lover of the scientific, and all this before he had reached the age of forty-eight. What a loss to the world when death called for him!

In his domestic relations, as son, brother, husband and father, he left a record that is without a flaw.

It is but little satisfaction for this Club to spread upon its records this poor tribute to the memory of Leverett L. Leggett, and to send a copy of it to his bereaved family; but it is all that we can do.

C. P. LELAND,
E. W. MORLEY,
W. R. WARNER, } *Committee.*

The resolution was unanimously adopted.

The report by Mr. E. P. Roberts, On the Trip of the Club to the Power House, was read by the Secretary.

The following resolution was then presented by Mr. Coburn and unanimously adopted: *Resolved*, That the sincere thanks of this Club be extended to our Brother Wason, President of the Electric Club, for the interesting, instructive and entertaining excursion of Wednesday evening of last week.

The President announced that Prof. Brashear will deliver a lecture under the auspices of the Club on the evening of May 30th, at the Y. M. C. A. Hall. The subject of the address will be "Color."

The tellers announced the result of the ballot for the proposed amendments of the Constitution as follows: Number of ballots cast, thirty-one; number in favor of amendments, twenty-eight; number opposed to amendments, three. The President declared the amendments adopted.

Prof. C. H. Benjamin then read an abstract of the paper entitled "Stresses and Deflections in Circular Hoops, under the Various Conditions of Loading," prepared by Messrs. Edwin J. Fort and C. W. L. Filkins, of Cornell University. This paper was discussed by Messrs. W. H. Searles and A. E. Brown.

Mr. A. E. Brown then presented a paper entitled, "Some of the Requirements of the Design and the Results of Tests of a new High Speed Electric Cantilever Crane for Shipbuilding," which was discussed by Messrs. Bidwell, Osborn and Thompson.

The meeting adjourned at 10.15. FRANK C. OSBORN, *Secretary.*

Western Society of Engineers.

314TH MEETING, MAY 2, 1894.—Parlor 44, Grand Pacific Hotel, Chicago, 8 P.M. 62 members and guests present. President Herr took the chair and called the meeting to order.

The minutes of the last meeting were approved.

The Secretary reported action of the Board of Directors as follows:

At the meeting held May 2d, Messrs. Jacob B. Rohrer and Dion Geraldine were elected to membership. The applications for membership of Messrs. Chas. S. Hill and Arthur H. Lloyd were received and placed on file. Mr. Thomas Appleton resigned his position as Librarian. The resignation was accepted and Mr. Charles J. Roney was elected Librarian to fill the vacancy.

On motion of Col. Burke the report of the Board of Directors was received and placed on file.

The Secretary then reported as follows:

The Secretary regrets to be obliged to report the death of Orlando H. Cheney, late Superintendent of Sewers of this City, who has been a member of the Society since 1886. Mr. Cheney died on the 13th day of April.

The Secretary also read a letter from Prof. J. B. Johnson, Chairman of the Board of Managers of the Association of Engineering Societies, which states that the efforts of this and other engineering societies to have their publications restored to the privilege of second-class rates, have been so far successful that on April 6th, the House of Representatives amended the Postal Department appropriation bill by adding a declaratory clause interpreting the old law so as to include such publications as were named in the Manderson-Hainer bill, and also the regular publications of Scientific, Engineering, and other professional societies. The object of this clause was to reverse the decision of the Department which has recently ruled out these publications.

The matter will now come up in the Senate, and this particular amendment will probably be opposed by the Post-office Department. Prof. Johnson suggests that short letters and petitions be sent to the members of the Senate appropriation committee and of the Senate committee on Post-offices and Post-roads, asking for the admission of our publication at second-class rates.

The Secretary also read a letter from Prof. Johnson, tendering the thanks of the Society for the Promotion of Engineering Education for the service of this Society in distributing 40 copies of its proceedings to as many engineering societies.

The Secretary also read a letter from Mr. Chanute, transmitting a letter from Mr. C. A. Bryce Cuxson, Secretary of the Society of Engineers of London, England, stating that the following resolution was unanimously passed by that society: "That the Society of Engineers desire to convey their thanks to the allied societies of the United States and Canada for the courtesy and hospitality shown by them to British Engineers at Chicago during the Columbian Exposition."

The report of the Secretary was received and placed on file.

The Librarian then made the following report:

Contributions to the library for the month of April are as follows: From President Herr: 67 bound volumes, 457 unbound volumes, pamphlets, etc. From Vice-President Mead: 6 bound volumes, 11 unbound volumes, and pamphlets. From Mr. John W. Weston: 4 bound volumes, and many odd numbers of the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES. From Mr. T. J. Nichol: 21 bound volumes, and many back numbers of technical journals. From Mr. Max E. Schmidt: 1 bound volume. From Mr. C. W. Irish: 6 bound volumes, and 2 unbound volumes.

From Mr. Isham Randolph: 2 illustrated maps and estimate of quantities of the Sanitary District. From Mr. Ralph Modjeski: 83 back numbers of technical journals. From Secretary Appleton: 1 bound volume. From Miss Emma Jacobson: 30 papers of World's Engineering Congress. From the U. S. Bureau of Education: 3 unbound volumes, and pamphlets. From the office of Chief of Engineers, U. S. A.: 6 bound volumes. From the City Engineer of Omaha: 1 bound volume. From the State Geologist of Iowa: 1 unbound volume. From the Institution of Civil Engineers, Great Britain: 1 unbound volume. From the U. S. Geological Survey: 21 atlas sheets. From Mr. J. J. R. Croes: 1 pamphlet. From the Jarecki Mfg. Co.: 1 bound trade catalogue. Total: 114 bound volumes, more than 1,000 unbound volumes, pamphlets, and odd numbers of technical journals, 5 framed photographs, 2 maps, and 26 atlas sheets.

The report of the Librarian was received and placed on file.

The report of the Treasurer, showing cash on hand April 30, 1894, $1081.40, was received and placed on file.

The report of the Committee on Memorial of Mr. A. Gottlieb was read by the Secretary.

On motion of Mr. Artingstall, it was ordered that the report be received, placed on file, and printed in the proceedings, and that a copy be sent to the family of the deceased.

It was moved by M. Artingstall, that a committee of three be appointed to draw up a memoir of Mr. O. H. Cheney. The motion was seconded and carried. The President appointed Mr. Artingstall, Mr. F. H. Davies and Mr. R. P. Brown, as the committee.

Mr. Charles V. Weston read a paper on the New Tunnel of the West Chicago Street Railway Co., near Van Buren Street.

The paper was illustrated with numerous blue-prints showing the construction in detail, and was discussed by Messrs. Casgrain, Hill, Artingstall and Liljencrantz.

It is expected that the paper and discussion will appear in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

The Secretary announced that the catalogues of the Portuguese Engineering Exhibit, which were mentioned at a previous meeting, had arrived, and that members who desired could obtain them, while the supply lasted, at ten cents a copy.

On motion the meeting adjourned.

THOS. APPLETON, *Secretary.*

Engineers' Club of St. Louis.

399TH MEETING, MAY 2, 1894.—The Club met at 1600 Lucas Place at 8.15 P.M. President Crosby in the chair; thirty-five members and sixteen visitors present. The minutes of the 398th meeting were read and approved. The Executive Committee reported the doings of its 162d meeting.

The Secretary reported that the Boston Society of Civil Engineers had adopted a by-law providing for exchange of members with other societies in the Association, and that the following societies had previously taken similar action: Civil Engineers' Club of Cleveland; Civil Engineers' Society of St. Paul; Wisconsin Polytechnic Society; Montana Society of Civil Engineers, and the Engineers' Club of St. Louis, where the movement originated.

An application from E. J. Spencer for transfer of membership from the Boston Society was announced.

The Secretary read a letter from the English Society of Engineers thanking the associated engineering societies for their entertainment during the Columbian Exposition.

Mr. Robert Moore then read a paper on "The Filtration of City Water Supplies in the Light of Recent Researches." He described primitive water supplies, and explained the development of the public water system for distribution over wide areas under pressure. Typhoid fever is directly traceable to water contamination. All water in streams is more or less contaminated, and the question of its purification has been given great study. Pipes or wells, sunk in sandy soil alongside of streams, afford natural filtration, but they supply limited quantities of water, and that water is always inferior to that of the neighboring stream.

The first artificial sand filter was built by James Simpson in 1839, and proved so successful that its use was shortly afterward made obligatory on all companies supplying water in London. In 1866 Mr. Kirkwood, on behalf of the city of St. Louis, made an extensive study of the problem of filtration, visiting many foreign cities. His report, which embodies plans for a complete filter system for St. Louis, is in the library of this club.

There appeared great doubt, however, whether sand filtration removed disease germs—in fact some authorities claimed that it increased them. The developments of recent years in methods of biological analysis have made it possible to determine this fact absolutely, and it has now been shown that sand filtration practically removes all the bacteria. This is further proven by typhoid and mortuary statistics from various cities.

Mr. Moore placed the cost of a filter system for the city of St. Louis at $2,000,000, and the annual expense of operation, maintenance and interest charges at $150,000. As the filtration of our water supply would undoubtedly reduce the number of typhoid cases by half, to say nothing of other advantages, the adoption of filtration for our water supply was strongly recommended.

In the discussion Mr. Holman stated that plans were being made and experiments conducted upon various systems. The water department would be ready to act in the matter when funds were available.

In the further discussion it was stated that most of the work in the filter bed is done by the thin top layer, and that the cleaning process consists mainly of scraping off this layer whenever it became so much clogged as to prevent the ready flow of water. It was anticipated that the filtering of 50,000,000 gallons of water per day would cause a deposit of 1,000 tons of mud, but most of this would be taken out in the settling basins, where fully 90 per-cent. would go down in the first eight hours. This would greatly lighten the task on the filters. It was shown that it would be desirable to treat the water with a coagulant, and also to cover the filter beds.

Messrs. Seddon, Kineally, Crosby, and Drs. Green, Ravold, Sanger und Bryson also participated in the discussion.

Adjourned. W. H. Bryan, *Secretary.*

Boston Society of Civil Engineers.

May 16, 1894.—The regular meeting of the Society was held at its rooms, 36 Bromfield Street, Boston, at 7.50 o'clock, P.M. President William E. McClintock in the chair. 138 members and visitors present.

The record of the last meeting was read and approved.

Messrs. George A. Carpenter, Lincoln C. Heywood, Peter Schwamb and Chester J. Wallace were elected members of the Society.

The Secretary read a communication from the English Society of Engineers, conveying their thanks for the courtesy and hospitality shown them at Chicago during the World's Fair by the allied societies of the United States and Canada.

Mr. F. P. Stearns gave a very interesting talk embodying the principal features of the joint report recently made to the Legislature by the State Board of Health and Metropolitan Park Commission on the improvement of the Charles River. With the aid of plans and lantern views Mr. Stearns explained in detail the proposed dam to be located near Cragie Bridge and the walls to be constructed along the basin. He showed that it would cost much less to construct the wall if the water in the basin was maintained at a high level by a dam than if it was permitted to rise and fall with the tide. He had thrown upon the screen a large number of views of the Alster Basin in Hamburg.

Mr. Edmund Hudson explained with the aid of the lantern the improvements that had been made in the water fronts of London, Paris and Berlin.

Mr. Quincy Pond, of Newton, exhibited a series of beautiful lantern views taken along the banks of the upper Charles River.

Mr. F. W. Hodgdon spoke of the effect of the tidal currents in Boston harbor and of the means that had been adopted to prevent any encroachment on the area of the tidal basin.

After passing votes of thanks to Mr. Hudson and Mr. Pond for their kindness in taking part in the evening's entertainment, the Society adjourned.

S. E. Tinkham, *Secretary.*

Association of Engineering Societies.

Vol. XIII. JUNE, 1894. No. 6.

PROCEEDINGS.

Western Society of Engineers.

315th Meeting, June 6, 1894.—The 315th meeting was held at Parlor 44, Grand Pacific Hotel, Chicago, at 8 p.m, June 6, 1894. Fifty-two members and guests present. President Herr took the chair and called the meeting to order.

The Secretary then reported action of the Board of Directors as follows:

At the meeting held June 6th, Messrs. Charles S. Hill and Arthur H. Lloyd were elected to membership. The applications of Messrs. William Graham, H. A. Boedker, and Edward Wilmann were received and placed on file.

The report of the Secretary was then read. This announced the death of our fellow member, Mr. Isaac Lincoln, which occurred at Albuquerque, N. M., on the 13th of March. The report also stated that some eighteen letters from foreign Societies had been received acknowledging with thanks the receipt of copies of "Engineering Education."

The Librarian then reported as follows:

Total contributions to the Library for the month of May, 65 volumes, 132 pamphlets, 4 framed photographs, 2 blue-print photographs, 12 sheets of statistics, 9 map sheets, 3 folio atlases containing 146 sheets, and various odd numbers of periodicals.

In addition, the Reading Room has received from the publishers, Maller's Building, Chicago, a subscription to the *Stationary Engineer;* and a subscription to *The Army Magazine*, from the publishers, Pontiac Building, Chicago.

It was voted that the thanks of the Society be tendered to Messrs. Shailer & Schniglau for the courtesy shown members in the free use of their steam barge for the excursion on June 2d.

It was moved and seconded that the July and August meetings be omitted this year.

After discussion, the question being put on a *viva voce* vote, the decision was in doubt. On a rising vote being called for by the Chair, there were nine in favor and eleven against. The motion was declared lost.

The first Wednesday in July falling upon the fourth of that month, it was voted that the next meeting be held on the second Wednesday in July.

On motion, the President appointed Messrs. D. Adler, E. F. Osborne and Louis Mohr as a committee to prepare a memoir of Mr. Isaac Lincoln.

In the absence of Mr. E. A. Rudiger, his paper on "Typhoid Fever and the

Epidemic at Ironwood, Mich., in 1893," was read by the Secretary. It described the situation of Ironwood, a mining town of some 12,000 inhabitants, who very generally used the water of shallow wells for drinking purposes. The water supplied by the water works, although discolored, as all water from streams in a wooded country is, was not usually unwholesome. Upon an outbreak of typhoid fever in the town an investigation was made, and this resulted in the discovery of some carcasses of dead animals on the banks of a small stream that discharged into the river a short distance above the water-works intake. This stream also drained a portion of the town. The carcasses had been deposited there by a member of the Board of Aldermen and Committee on Health, who afterwards died of typhoid fever.

The paper also treats of bacteria, their nature and growth, and their effects on the human system.

Mr. Samuel M. Rowe then read a paper on the "Halsted Street Lift Bridge," which was illustrated by blue-prints. The paper was discussed by Messrs. Strobel, C. V. Weston, Goldmark, Horton and Evans. Those members who visited the bridge on the excursion of June 2d were, of course enabled to appreciate the description of the operation of the bridge much better than those who had not seen it.

As the papers will probably appear in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES no attempt will be made to give abstracts of them here.

At the close of the discussion the meeting adjourned.

THOS. APPLETON, *Secretary*.

Engineers' Club of St. Louis.

401ST MEETING, JUNE 6, 1894.—The Club was called to order at 8.15 P.M., at 1600 Lucas Place, by the Secretary, both the President and Vice-President being absent. Mr. Robert Moore was chosen chairman *pro tem.* The minutes of the 400th meeting were read and approved. The Executive Committee reported the doings of its 164th meeting, announcing the receipt of the resignation of Mr. Charles W. Melcher as Treasurer, and recommending its acceptance. On motion the resignation was accepted. Mr. Thomas B. McMath was elected by ballot to fill the vacancy. On motion the Executive Committee was directed to audit the accounts of Mr. Melcher, and to turn over the assets to the new Treasurer. The Executive Committee having approved the application for membership of Mr. E. W. Sterne, that gentleman was balloted for and elected.

A paper by Mr. A. A. Stuart, entitled "Some Notes on the Brooklyn Elevated Railway, Brooklyn, N. Y.," was then read by Mr. Julius Baier. The paper was accompanied by detailed drawings, showing the essential features of the structure and buildings, together with the specifications for the work, and a map showing the area served. Particulars of improvements made in recent construction, together with first costs, cost of operation and of maintenance, were also presented. The historical features of the enterprise were briefly touched upon. In the discussion, which was participated in by Messrs. Schaub, Moore, Flad and Wheeler, the details of connection between posts and foundations were brought up, as well as the present condition of the iron work of old structures, and the amount of vibration to which they are subjected.

A paper by Mr. J. W. Woermann on "Concrete Construction on the Illinois

and Mississippi River Canal" was read by Mr. P. M. Bruner. This work, which is better known as the Hennepin Canal, connects the Illinois River near its great bend with the Mississippi near Rock Island. An elevation of over 200 feet is crossed, so that numerous locks are required. It being impossible to get a good grade of limestone near at hand for the masonry, it was decided to use concrete exclusively for that portion of the work now in hand. It, therefore, represents one of the most extensive pieces of concrete construction in this country. The processes employed, the proportions of the ingredients, the amount of labor, rate of progress, and total cost were fully stated.

A brief discussion followed, in which Messrs. Moore, Schaub, Bryan and Baier participated.

Adjourned. W. H. Bryan, *Secretary.*

Engineers' Club of Cleveland.

Chamber of Commerce Rooms, June 12, 1894.—The meeting was called to order at 7.50 p.m., by the President. Thirty-seven members and visitors were present.

The record of the meeting held on May 8th was read and approved.

The President appointed Messrs. Geo. E. Gifford and C. G. Force tellers for the evening.

Prof. C. H. Benjamin read a report from the Board of Managers of the Association of Engineering Societies in regard to the change in postal laws affecting the Journal of the Association.

Mr. H. C. Thompson moved that a committee be appointed to make necessary arrangements for a picnic to be held during July; the location, the date and other arrangements to be left entirely with the committee, and said picnic to take the the place of the regular July meeting. The motion was carried, and the President appointed the following committee: Messrs. A. H. Porter, C. G. Force, F. A. Coburn, W. P. Dittoe and C. W. Wason.

Prof. C. H. Benjamin moved that a vote of thanks be tendered Mr. Swasey for his thoughtfulness and pains in providing for the Club the enjoyable lecture by Dr. J. A. Brashear, of Allegheny, Pa., and also that a vote of thanks be tendered Dr. Brashear for his kindness in consenting to deliver this lecture before the Club and its friends. The vote of thanks was unanimously passed.

The tellers announced through the Secretary the election to Active Membership of Messrs. N. S. Crouch and W. S. Thompson.

Prof. C. F. Mabery then presented a very interesting paper, entitled "The Investigation of the Composition of Ohio and Canada Petroleum." The paper was discussed by Prof. J. W. Langley, Prof. E. M. Morley and Messrs. Swasey, A. E. Brown, N. B. Wood, M. E. Rawson and C. M. Barber.

The meeting adjourned at 10 o'clock.

F. C. Osborn, *Secretary.*

Boston Society of Civil Engineers.

June 20, 1894.—A regular meeting of the Society was held in its rooms, 36 Bromfield Street, Boston, at 7.50 p.m., President W. E. McClintock in the chair. Sixty-seven members and visitors present

The record of the last meeting was read and approved.

Messrs. Albert S. Crane, Loring N. Farnum, Louis Hawes, Horace J. Howe and Oscar H. Tripp were elected members of the Society.

The President announced the death of Hiram Nevons, a member of the Society, which occurred May 27, 1894, and a committee, consisting of Messrs. R. C. P. Coggeshall, A. F. Noyes and Dexter Brackett, was appointed to prepare a memoir.

Mr. Freeman C. Coffin read a paper entitled "Tests of Cement Joints for Sewer Pipes." The paper was followed by a general discussion of joints in sewer pipes, Messrs. F. P. Stearns, E. S. Dorr, H. H. Carter, H. D. Woods, and others, taking part.

President McClintock then gave an account of the bicycle track recently constructed at Waltham, Mass., upon which the fastest mile has been made.

Adjourned. S. E. TINKHAM, *Secretary.*

Association of Engineering Societies.

Vol. XIII. JULY, 1894. No. 7.

PROCEEDINGS.

Western Society of Engineers.

316th Meeting, July 11, 1894.—The 316th meeting was held at Parlor 44, Grand Pacific Hotel, Chicago, at 8 p. m., July 11, 1894. Thirty members and guests present.

In the absence of the President and of both Vice-Presidents the Secretary requested Mr. T. T. Johnston to take the chair. Mr. Johnston did so, and called the meeting to order.

The minutes of the last meeting were approved.

The Secretary then read the report of the Board of Directors as follows:

At the meeting of the Board held June 20th, the Committee on Appointment of Standing Committees reported as follows: "We recommend the appointment of the following committees of the Board of Directors: (1) Committee on Publications. (2) Committee on Membership. We further recommend that the Society at its next meeting be requested to authorize the appointment of the following committees of five members each—(1) Committee on Library. (2) Committee on Entertainment and Excursions."

This report was accepted, and Messrs. Morison, Hunt and Barnes were appointed as the Committee on Publications, and Messrs. Strobel, Draper and Mead as the Committee on Membership.

Messrs. H. A. Boedker, William Graham and Edward Wilman were elected to membership. The applications of Messrs. George E. Thomas and Moulton J. Cross were received and placed on file. The resignation of Mr. Benjamin Hyde was accepted.

The following resolution was adopted:

Resolved, That in case the Society decides to appoint a Committee on Excursions, as recommended at the last meeting of this Board, that it is the sense of this Board that the Society should not be responsible for any debts contracted by said Committee, and that none of the expenses of any proposed excursions be paid out of the Society funds.

On motion it was voted that the report of the Board of Directors be received and filed, and that its recommendations be concurred in.

The Librarian then read his report as follows:

Accessions to the Library for June, 1894.

Total, 111 volumes, 125 pamphlets, including 25 on Biltmore Forest, for distribution; 4 volumes periodicals, unbound; 134 numbers of periodicals, 2 photographs, 15 lift-bridge views, for distribution; 2 sets bridge specifications, 1 patent specification, 2 maps, 1 atlas of plates.

ACCESSIONS TO THE READING ROOM FOR JUNE, 1894.

From Charles S. Hill, Chicago: Subscription to *Engineering News*, from June 1, 1894.

From the *Western Electrician*, Chicago: Subscription to the *Western Electrician*, from June 23, 1894.

From publishers of the *Master Steam Fitter*, Chicago: Subscription to the *Master Steam Fitter*, from June, 1894.

The Reading Room receives regularly 20 monthly, 10 weekly and 2 quarterly publications.

One or more numbers of the current volumes of 20 other publications can also be found in the Reading Room.

The Committee appointed to prepare a memoir of Mr. Lotz reported a memoir, which was read by the Secretary.

It was voted that the report be received and placed on file, and that a copy be sent to the family of the deceased.

It was voted that the President appoint two committees of five members each, as recommended by the Board of Directors: (1) Committee on Library; (2) Committee on Entertainments and Excursions. The President has since appointed the following members as such committees.

Committee on Library: Messrs. O. Chanute, John Lundie, Fred. Davis, H. M. Sperry and Chas. J. Roney.

Committee on Entertainments and Excursions: Messrs. Horace E. Horton, Robert A. Shailer, Ferd. Hall, Jas. J. Reynolds and Emil Gerber.

Mr. Charles C. Stowell, of Rockford, Ill., then read a paper on the recently constructed covered reservoir of the Rockford water works. This reservoir has walls of cement concrete, covered with an arched roof of concrete and iron. The outside dimensions of the reservoir are 152 by 62 feet. It is partly in excavation and partly above ground. When full, the water will be 20 feet deep. The arched roof has a span of 55 feet. Ribs 7 feet center to center were built, using a 7-inch channel iron wrapped with metallic lathing as a foundation for the concrete. The space between the ribs was covered with concrete 2 inches thick, with metallic lathing imbedded. The wells and the pumping station were described.

After remarks by Messrs. Brown, Modjeski, Johnston and Appleton, the next paper by Prof. D. C. Jackson, of Madison, Wis., on the "Electrolysis of Iron Pipes caused by the Return Current of Electric Railroads," was read by the author.

The paper described experiments made to determine the chemical reactions which take place, as well as investigations made on several electric railroads, showing that the author had made thorough and careful studies of this matter of great importance to all corporations owning any kind of metallic conduits buried in the ground, as well as of especial interest to the electric railway companies. This subject apparently is not well understood at present, but occupies the attention of many bright minds.

Interesting remarks upon the subject were made by Mr. O. M. Rau, of Milwaukee Street Railway system, and Mr. A. V. Abbott, of the Chicago Telephone Co.

The discussion was also participated in by Messrs. Shnable, Geo. Weston, Davies and others. The meeting then adjourned.

The attendance at the meeting was less than the average number, owing perhaps to the hot weather, but the meeting was pronounced one of the most interesting and profitable that has been held this year.

THOS. APPLETON, *Secretary.*

Association of Engineering Societies.

Vol. XIII. AUGUST, 1894. No. 8.

PROCEEDINGS.

Engineers' Club of Minneapolis.

March 19, 1894.—Regular meeting at the Public Library. The meeting was called to order by President F. W. Cappelen, at 8 P.M.

The record of the meeting of February 19th was read and approved.

The following communications were presented:

From Prof. J. B. Johnson, in charge of the United States Government Timber Tests, requesting members to urge their representatives in Congress to aid the passage of the special bill introduced by Senator Coke, of Texas, making appropriations for the continuation of the tests.

From Prof. Johnson, from Senator Charles F. Manderson, from Representative E. J. Hainer, and from Messrs. R. Angst, W. D. Washburn and L. Fletcher, favoring the joint bill extending second-class mail rates to the publications of engineering and other societies. It was stated that the Post Office Department opposes the change.

From Mr. John C. Trautwine, Jr., Secretary of the Association of Engineering Societies, soliciting memoranda from the professional experience of members, for use in the department of "Notes and Communications" in the Journal.

From the Executive Committee of Engineering Societies at the Columbian Exhibition, a report.

From Prof. Johnson, a letter transmitting a pamphlet descriptive of Sherman's Aërial Hoisting, Carrying and Distributing Apparatus.

From Messrs. O. Chanute and Max E. Schmidt, letters transmitting the thanks of the Society of German Engineers for their entertainment in Chicago.

From Prof. J. B. Johnson, Chairman of the Board of Managers of the Association of Engineering Societies, a bill for $31.00, being the first quarterly assessment for the year 1894. On motion, the Treasurer was authorized to pay this bill.

From Mr. S. Whinery, letters and telegrams changing the time for reading his paper on Asphalt Street Paving to April 16th.

Mr. J. E. Howe read a paper on City Pavements.

In the informal discussion which followed, Mr. James E. Snyder explained the reduction in the cost of cedar block pavement by the fact that during the first three years of its use it came *via* Chicago, whereas the present freight rates are but one-half of what they were by that route.

Mr. George C. Andrews suggested paving with granite blocks on the sides of

the principal streets where horses are allowed to stand, and with cedar blocks in the center, where most of the driving is done.

Mr. Howe stated that in Salt Lake City granite is thus used in combination with asphalt.

Mr. Andrews thought that cedar blocks, as sprinkled, are bad in gutters; that a horse slips more on the wet wood than on granite.

Mr. E. T. Abbott asked how cedar blocks can be laid as cheaply as they are. He was unable to figure them at less than 90 cents, and in Chicago they cost $1.00.

Mr. Snyder replied that in Chicago dock rent is very high. Detroit pays $1.80 with concrete, foundation 60 cents, and $3.50 for granite.

Mr. Cappelen, in answer to a question from Alderman Loye, explained the making of concrete, and described the pavements of Paris, France.

Mr. Abbott held that the city should put an arbitrary price on the replacing of pavements, and should do the work itself, collecting the charges from the plumbers.

Mr. Cappelen thought that the use of tar was probably advisable, on sanitary considerations, but of little use as a preservative unless refined.

Mr. Snyder believed that pitch and gas tar hold the gravel until it is driven into the ends of the blocks.

Mr. Cappelen argued that 50 per cent. of the cost of repairs is probably chargeable to the tearing up of pavements.

Mr. G. W. Sublette thought that the concussion of horses' shoes, in light driving, is as destructive to pavements as is heavy traffic.

Mr. J. E. Howe mentioned some cases in which planks had lasted better on a clay than on a sand foundation.

Mr. G. W. Sublette read a paper drawing some conclusions as to the comparative economies of different pavements.

Further discussion was postponed, and the meeting adjourned.

There were present Messrs. Abbott, Andrews, Ahara, Cappelen, Dunham, Dutton, Howe, Hoag, Nexsen, Redfield, Sublette, and Snyder, members; and Messrs. Loye, Humphrey, and Caldwell, guests.

ELBERT NEXSEN, *Secretary.*

APRIL 16, 1894.—Regular meeting at the Public Library. At 8 P.M., in the absence of the President, Vice-President J. M. Haze called the meeting to order.

On motion, the reading of the minutes of the preceding meeting was postponed, and

Mr. Wm. A. Pike introduced Mr. S. Whinery, C. E., of Cincinnati, Ohio, who read a paper on Asphalt Street Paving.

The paper was informally discussed. Mr. Humphrey took exception to a statement that the life of a brick pavement is nine years. It was stated that State Street, Columbus, Ohio, was paved in 1888, and carried 34 tons per square foot per day, and that the Clayton Block, brick, in Cincinnati, last year carried 60 tons.

Mr. Whinery believed that the brick pavements of Charleston and Wheeling are covered with a cushion of sand, and stated, in reply to a question, that washing is a good way of cleaning asphalt pavement, but that hand-sweeping is the best and the cheapest. The aim of the makers is to produce a mixture which will maintain the same average hardness both in the North and in the South.

It was moved and seconded that the thanks of the Club be extended to Mr.

Whinery for his instructive paper, and that he be requested to furnish a copy of it for publication in the JOURNAL of the Association. A member of the Civil Engineers' Society of St. Paul, a number of whose members were present by invitation, requested that the members of that society who were present should be allowed to vote on the motion, which was then unanimously adopted.

On motion adjourned.

ELBERT NEXSEN, *Secretary.*

MAY 21, JUNE 18, JULY 16 AND AUGUST 20, 1894.—No quorum.

Western Society of Engineers.

317TH MEETING, AUGUST 1, 1894.—The 317th meeting was held at Parlor 44, Grand Pacific Hotel, Chicago, at 8 P.M. Forty-nine members and guests present.

In the absence of the President, Vice-President Mead took the chair and called the meeting to order.

The minutes of the last meeting were approved.

The Secretary reported action of the Board of Directors as follows:

At the meeting of the Board of Directors held this day, Messrs. Moulton J. Cross and George E. Thomas were elected to membership; the application of Mr. Christopher H. Snyder was received and placed on file; and the report of the Committee on Publications was received and 'placed on file, and recommended to the Society for adoption.

The Librarian then reported accessions to the Library for the month of July, as follows: Total accessions, 44 volumes, 197 pamphlets, 12 numbers of periodicals, 12 specifications, 1 atlas, and 43 copies of a pamphlet on the Sanitary District of Chicago (for distribution).

The report of the special committee of the Board of Directors, the Publication Committee, being called for, Capt. Hunt reported as follows, in the absence of Mr. Morison, Chairman:

CAPT. HUNT: The result of our deliberations is given in the report which we submitted verbally to the Board of Directors to-day. Under our agreement with the Association of Engineering Societies, we must give three months' notice not later than October 1st of this year, if we desire to terminate the agreement on the 31st day of December next. We most earnestly recommend that such notice be served.

The report of the Committee is as follows:

TO THE PRESIDENT AND BOARD OF DIRECTORS, WESTERN SOCIETY OF ENGINEERS.

Gentlemen: Your Committee on Papers and Publications would respectfully report that they have given the matter of the publication of the papers read before your Society, and the discussions on them, serious consideration, and as the result would recommend the withdrawal of your Society from the Association of Engineering Societies. Under the law of that Association, it is necessary for at least three months' notice of a desire to withdraw to be given before the end of any fiscal year. Therefore, if the Society approves of our recommendation, such notice must be given not later than immediately following the Society's September meeting.

Our conclusion was reached because we found the assessment on the Western Society to the Association of Engineering Societies for the current year has been $648.00, and that the remainder of the year will call for $525.00 additional. The cost of publishing the proceedings of your meetings will amount to about $204.00 additional, making a total of $1,377.00 for the publication of the papers and proceedings. We also found that so far this year but one of the Western Society's papers has been published in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, making that one paper cost $648.00.

We learn that your Secretary has been assured by the Secretary of the Engineering Societies that another of your papers will appear in the JOURNAL not later than next month. The failure to publish some of the Western Society's papers does not altogether rest with Secretary Trautwine, as he only prints such papers as the direction of the various Societies request; but this does not account for the delay in putting the designated papers in print.

We think it would add to the reputation of the Western Society of Engineers to have their own publication, and we believe that the certainty of all accepted papers, together with the discussions on them, being promptly printed and circulated in such a publication, would lead to the contribution of valuable papers from the members of the Society.

An estimate made on the basis of the cost and number of the Proceedings which the Society now issues monthly, shows that the cost to your Society of publishing your own Transactions would not exceed $1.88 per page. If we estimate on thirty pages monthly, which could perhaps be issued in the form of quarterlies of 120 pages each, the annual cost to your Society would be $676.80. The Proceedings which your Society now issues would form part of this issue. The total cost, therefore, of printing Proceedings and Transactions would be about one-half of the present cost of the JOURNAL and the Proceedings. The reproduction of drawings would absorb a portion of the other half, as against which there would be some profit from advertisements. We feel confident that at least $400.00 could be saved yearly.

Our members would not receive the papers of other Societies now published in the JOURNAL, but as an offset to this, their own papers would be more promptly and more fully published. It might be that a plan of interchange of Proceedings between the members of your and the members of other Societies could be arranged, as is the case with the railroad clubs in this country. With such a plan, each member would get the Proceedings of all the other Societies agreeing to the plan, by a small additional payment, as the cost of additional copies necessary would be comparatively small.

Moreover, the Society is seeking to build up a library. Under the present arrangement we cannot secure for it any exchanges; if we published our own Proceedings, many such could be obtained.

Respectfully submitting the above report, we remain,

Your Committee,

GEO. S. MORISON,
ROBERT W. HUNT,
DAVID L. BARNES.

CHICAGO, August 1, 1894.

Of course, if we do cut ourselves off from the JOURNAL of the Associated Societies the members will not receive the papers from the other Societies, but they will get our own, and we believe that the class of papers which will be pre-

sented by our members will be of a better and higher class if the authors are confident that they will be published immediately after the reading and circulated at least among our own membership. Another point which governs us in our recommendation is our desire to build up our library and to secure for it the exchanges of the scientific societies of this country. We cannot get them as members of the Association. It is a rule of publications well established that they will make but one exchange, and of course if they will give to the Western Society in exchange for the JOURNAL of the Association, all the other societies would have the same right to ask for it, and either they or ourselves would be refused. We believe that we can make a publication of our own which will entitle us to exchange with these various other organizations and scientific publications, and will thus add to the value of our library. In view of the fact that we are not rich, it is better to save from $500 to $600 a year in publication, if we can, and give ourselves more credit and greater standing among the societies of the country.

MR. STROBEL: I move that the report of the committee be received and that the subject be made a special order of business for the next meeting. I think there are a great many members of the Society interested, and they should have an opportunity of being present and of being heard. There is a good deal to be said on both sides of this question. It is a matter in which each member is much interested, and I think the decision, when it comes, ought to be the result of a full discussion. Seconded.

THE CHAIR: Your committee's estimate of $1.88 per page for the continuous publication of the bulk of the journal of this Society seems fully high enough. The State Society publishes an annual report, and I know that this year the contract is for 1500 copies at $1.23 a page; the pages are practically as large as the pages of the journal. Possibly the paper in the journal is somewhat better, but my judgment would be that the expense would come well within the committee's estimate. I simply mention this as an actual figure of what work of that class is done for in the State.

The motion of Mr. Strobel was then put to vote and carried.

Under reports of Special Committees, Mr. Chanute made the following report for the Library Committee:

MR. CHANUTE: The Library Committee, having received no special instruction, was at first at a loss to know what was before it to do, and it concluded that it would be preferable to lay out, so far as it could, a general plan to be followed in increasing and improving the library, and to submit this plan to the Society and receive instructions as to what course should be pursued. It has therefore made the following report:

The Committee on Library, appointed in accordance with a resolution passed at the last meeting of the Western Society of Engineers, begs to submit the following report for consideration:

1. *General Policy.*—The Engineering Library of the Society now comprises about 1,400 volumes, in addition to many pamphlets, maps, etc. It is but little used because of its limited extent; but, small as it is, it is said to be larger than that of any other engineering association west of New York City; and, in view of the population and central location of Chicago, it would seem to be a good nucleus for the collection of a large technical library, should the Society decide to adopt that policy. To accomplish this, and to make sure that the movement shall not relax, it would seem desirable to adopt now adequate plans for continuous growth, for permanent care of the books and for easy and extensive use of them.

2. *Scope.*—The Committee believes that the scope of the library should broadly comprise all branches of engineering, *i.e.*, the civil, mechanical, mining, metallurgical, electrical, military and naval specialities and allied subjects. Also that liberal rules should be adopted to make it accessible to all persons interested in these several studies, so that it may prove truly useful.

3. *Methods of Getting Books.*—The movement must unfortunately be inaugurated practically without a fund, and it will be necessary, at the beginning, to rely chiefly upon donations.

The Committee therefore suggests the issuance of a circular, substantially in the form submitted in Appendix No. 1, to be printed and sent out repeatedly to members, societies, government officials, business men and others, soliciting gifts of books, so as to obtain whatever may be gathered together in this way.

If we can satisfy such persons that their books will be permanently well cared for and made useful, many valuable works will doubtless be obtained. There will, of course, be many duplicates, and some odds and ends, but some of these can be disposed of by exchange and sale, and sets may be completed by purchase or otherwise.

In order to make the library really attractive, however, it should contain the more recent and valuable books of reference. Some of these will have to be purchased, yet the Committee suggests that a number may be obtained from the publishers, through letters substantially in form as per Appendix 2, soliciting new books, and offering as a compensation to review them in the monthly proceedings issued to members.

In order to determine what books to be purchased are most in demand, it is suggested that a register be opened at the Society's rooms, upon which members may enter the title of such books as they desire to have obtained; the expediency of their purchase to be passed upon by such authority as the Board of Directors shall indicate.

4. *Obtaining Means.*—If the Library is to be made attractive and to grow steadily, it is very evident that money will have to be expended. The Committee estimates that $300 will be sufficient for this year. It suggests, therefore, that in addition to the $1,000 now being raised to carry out the recommendations of the Reorganization Committee, a special library fund be inaugurated, to be held as a trust, and drawn upon for no other purpose but the extension of the library. It suggests that not only shall members contribute to this fund, in proportion to their means, but that they shall make known this effort to collect a library to manufacturers and business men interested in engineering matters, so as to give them an opportunity of contributing thereto, either in money or books.

It is hoped that some wealthy persons may eventually contribute to this library large gifts or bequests, to which their names may be attached.

In order to start such a fund, one of the Committee, Mr. F. Davis, has obtained subscriptions to the amount of $125, to which it is hoped that the members will make a substantial addition.

5. *Use of Library.*—The library is now but little used, because it is small, incongruous and incomplete. It is believed that by the means indicated, it can be increased to about 5,000 volumes within five years. This might overflow the rooms of the Society, but it is suggested that, in that event, an arrangement might be made with one of the large public libraries in Chicago to furnish house room, and that eventually this collection of technical literature might grow to 25,000 or more volumes.

With that view the Committee recommends that the library be made accessible now, not only to the members of the Society, but to such persons interested in engineering subjects as shall be properly accredited by a member. Still further to make the library accessible, the Committee recommends that the experiment be tried for a time to circulate a part of it. For this purpose the books would have to be divided into two classes, first, Books of Reference; to be consulted only at the rooms. Second, Circulating Books; such as are easily replaced, which may be taken out for two weeks, by members only, upon deposit of their value, and the payment of a fee, say 10 to 25 cents, according to value. A fine of triple these rates per week to be imposed for each week that the book is retained beyond the original two weeks, until this fine amounts to a forfeiture of the deposit, when the book is to be replaced with the proceeds of the forfeiture. Express or postal charges to be paid in addition by out-of-town members.

6. *Catalogue.*—In order to make the Library really useful, it is necessary that there should be a catalogue. Mr. Roney, the Librarian, is now compiling a finding list. It is recommended that this list be printed and issued to the members. An edition of 500 copies will cost about $50, and part of this may be offset by advertisements. The balance may be paid out of the fund now inaugurated by the Committee.

The latter also recommends that the Board of Directors shall formulate rules under which the Librarian may exchange or dispose of duplicate or irrelevant books.

It is desirable that the Society shall pass upon the expediency and adequacy of the methods proposed, in order that the movement shall be carried on upon a defined plan.

Respectfully submitted,

O. Chanute,
F. Davis,
J. Lundie,
C. J. Roney,
H. M. Sperry,
Committee.

The Chair: Gentlemen, the report of the Library Committee is before you; what will you do with this report?

Mr. Strobel: I think the report is a very good one, and it should receive the cordial endorsement of the Society, with one exception. We ought not all at once to undertake to do too much. I do not approve of the circulating library feature. The Librarian has as much as he can now do, in arranging the library and getting out a finding list and procuring additions to the library. I think that is the most important work that he can do now, and he ought not to divert his attention to anything additional. We have very little money, as everyone knows, for the compensation of a librarian; it is not adequate for the services rendered, and it comes from a special fund which we get by voluntary subscription. If it were attempted to circulate books, there would be more disadvantage than advantage coming from it. I do not think we have a book that is not a reference book; and there are very few duplicates. In case of those duplicates, it would not be a disadvantage to have members take a copy, but otherwise, if a member takes the trouble to go to the rooms of the Society to find a book and discovers that that book is not there, he will be very much disappointed. The few that will have those books will reap the benefit, and the many that may

come to use the library as a consulting library will have the disadvantage. We ought in that matter to be governed somewhat by precedent. I believe that nearly all the endowed libraries are simply reference libraries, and I think that in the present stage of this matter we ought not to undertake more than they do with all their money and all their experience. I would therefore move that the report be received, that it be printed in the proceedings, and that the program, as outlined, has the approval of this meeting, with the exception that it is not considered expedient at this time to circulate books.

The motion was seconded and carried.

Mr. Isham Randolph then read a paper entitled "A Prefatory Description of the Organization and Works of the Sanitary District of Chicago."

The paper was illustrated by means of maps and diagrams.

Remarks were made by Messrs. Cooley, Morehouse and others, after which the meeting adjourned.

It is expected that the paper and discussion will be published in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

The Excursion Committee has in view an excursion to the Sanitary District during the Fall. It will probably be best to make two or more trips, as it is impossible to give this great work anything but a superficial examination in one day. Other papers describing details of the work are promised during the next few months.

THOS. APPLETON, *Secretary.*

Association of Engineering Societies.

Vol. XIII. SEPTEMBER, 1894. No. 9.

PROCEEDINGS.

Engineers' Club of Cleveland.

Rooms of the Cleveland Electric Club, Aug. 14, 1894.—The meeting was called to order at 7.50 p.m. by the President. Thirty-one members and visitors were present.

The report of the meeting held June 12th was read and approved.

A verbal report from the Committee on Rooms was presented by Mr. C. W. Wason, and was supplemented by a verbal report from Mr. A. H. Porter.

A report from the Committee on Annual Picnic was read by Mr. A. H. Porter.

A report was presented by the committee appointed to prepare a memorial of the life of Mr. C. B. Krause, late member of this Club, who died April 4, 1894. It was moved and carried that the report be accepted and spread upon the minutes.

The President announced the death of our Treasurer, Mr. C. P. Leland, and it was ordered that a committee be appointed to prepare a suitable memorial. The President appointed on this committee Messrs. E. A. Handy, Luther Allen, and W. H. Searles.

It was moved and carried that a vote of thanks be extended to The Electric Club of Cleveland for its kindness in extending the use of its rooms. Mr. C. W. Wason, President of The Electric Club, then responded by tendering to the Civil Engineers' Club of Cleveland the use of the rooms at any time.

The tellers, Messrs. H. C. Thompson and A. Honsberg, announced the ballot for treasurer to succeed the late Mr. C. P. Leland, as follows:

Mr. J. C. Wallace, 12; Mr. James Ritchie, 7. Mr. Wallace was therefore declared elected Treasurer to fill the unexpired term of Mr. Leland.

Mr. J. N. Richardson then presented the paper of the evening, entitled: "Steel Construction as Applied to Buildings." The paper was discussed by Messrs. C. W. Wason, A. H. Porter, W. H. Searles, Ambrose Swasey, H. C. Thompson, James Ritchie, F. C. Osborn, N. B. Wood, W. W. Sabin, A. Lincoln Hyde, Peter Neff, Jr., and S. T. Dodd.

The meeting adjourned at 9.45 p.m. Frank C. Osborn, *Secretary.*

Rooms of the Cleveland Electric Club, Sept. 11, 1894.—The meeting was called to order at 7.50 p.m. by the Vice-President. Thirty members and visitors were present.

The report of the meeting of August 14th was read and approved.

Mr. Searles reported, on behalf of the committee appointed to prepare a memorial of the life of Mr. C. P. Leland, that on account of the absence of two members of the committee from the city, they were unable to make a report at this meeting.

Prof. C. H. Benjamin then read the paper of the evening, entitled: "Notes on the Strength and Elasticity of Steel Castings." This paper was discussed by Messrs. C. W. Wason, E. P. Roberts, Ludwig Herman, A. H. Porter, and W. R. Warner.

An informal discussion was then held on the subject of the contemplated new bridge across the Hudson River at New York.

The meeting adjourned at 10 P.M. FRANK C. OSBORN, *Secretary.*

Western Society of Engineers.

318TH MEETING, SEPTEMBER 5, 1894.— The meeting was held in Parlor 44, Grand Pacific Hotel, Chicago, at 8 P.M. Fifty-two members and guests present.

President Herr took the chair and called the meeting to order.

The minutes of the last meeting were approved.

The Secretary read the report of the Board of Directors, as follows: At the meeting of the Board of Directors, held to-day, the Treasurer reported cash on hand $522.53, of which $44.67 is in the special fund. Bills amounting to $356.53 were approved and ordered paid out of the general fund, and bills for $41.67 approved and ordered paid from the special fund.

The application for membership of Mr. C. H. Snyder was taken from the files and he was elected to membership.

The following applications for membership were received and placed on file: Herman R. Abbott, Lindon W. Bates, C. M. Higginson, F. P. Kellogg, R. P. Lamont, B. B. Newton and H. C. Powell, of Chicago; Warren B. Hazen, of St. Joseph, Mo.; and J. P. O'Donnell, of London, England.

The letters of Prof. J. B. Johnson, Chairman of the Board of Managers, and John C. Trautwine, Jr., Secretary, of the Association of Engineering Societies, were referred to the Society.

The Secretary also reported that the fifteen souvenirs and ten medals, mentioned in the letter from the French Society of Engineers, had been received.

The report of the Board was placed on file.

Mr. Horton Chairman of the Committee on Excursions and Entertainments, reported that an excursion to the Sanitary District had been arranged for the coming Saturday, and that the details had been announced in a circular to the members.

On motion, the report was received and placed on file.

In the absence of the Chairman of the Committee on Reorganization, remarks were made by Mr. Cooley and by the Secretary, to the effect that the Committee had held several meetings, but, owing to the fact that several members of the Committee had removed to New York, it was exceedingly difficult to get the Committee together.

In the absence of the Chairman of the Library Committee, Mr. Roney reported that the Committee had authorized the issuing of a circular to the members of the National Irrigation Congress, now in session at Denver, and to the American Association of Irrigation Engineers, which meets in Denver immediately after the close

of the Congress. This circular is an invitation to the members of the Congress and of the Association to contribute to the library of the Western Society of Engineers literature of all kinds respecting irrigation. Mr. E. F. Cragin, the Illinois delegate to the Congress, had expressed great interest in the matter and had promised to give it his personal attention. Eight hundred copies of such a circular were sent as suggested.

The report of the Librarian, showing the accessions to the Library during the month of August, was presented.

THE PRESIDENT: The next matter for consideration is the question of the withdrawal of our Society from the Association of Engineering Societies, which at the last meeting was made a special order for this evening. It is necessary to give three months' notice of withdrawal, and the withdrawal must be at the end of the Association's fiscal year, which now ends with the calendar year. There are several papers here relating to the matter, and I will call upon the Secretary to read them.

The Secretary then read a letter from the Chairman of the Board of Managers of the Association, Prof. J. B. Johnson.

At the request of Mr. Benezette Williams the Secretary also read the printed letter of Mr. John C. Trautwine, Jr., Secretary of the Association, upon the same subject. He read also the report of the Committee on Publications, which was submitted at the last meeting.

Mr. T. J. Johnston then made the following motion:

Moved that the recommendations of the Committee be concurred in, and that it be ordered that the Society withdraw from the Association of Engineering Societies. The motion was seconded.

The motion was discussed by Messrs. Cooley, Sperry, Strobel, Benezette Williams, D. L. Barnes, Roney, Johnston, Maddock, Morehouse, C. V. Weston and the President.

MR. STROBEL: I move to amend the motion just made by adding "and that a vote on this resolution be taken at an adjourned meeting two weeks from to-night."

The amendment was seconded by Mr. Morehouse, and carried. Ayes, 24; noes, 9.

The motion, as amended, was carried.

Mr. Benezette Williams moved that the Secretary be instructed to print the discussion as expeditiously as possible and send it to each member of the Society. Motion seconded.

After remarks by Messrs. Williams, Barnes, Cooley and Sperry, Mr. Williams offered as an addition to his original motion that the printed discussion include the letter of Prof. Johnson, Chairman of the Board of Managers.

The addition not being accepted by the seconder, the original motion was put to vote and declared lost.

Mr. Strobel offered a motion that the Committee on Distribution of Medals and Souvenirs received from the Society of Civil Engineers of France, be instructed to draw up a fitting acknowledgment to be sent to that Society. The motion was seconded and carried.

On motion, the meeting adjourned to meet September 19th.

THOS. APPLETON, *Secretary.*

Boston Society of Civil Engineers.

September 19, 1894.—A regular meeting of the Boston Society of Civil Engineers was held at its rooms, 36 Bromfield Street, at 8 oclock P.M. Mr. Albert F. Noyes in the chair ; forty members and visitors present.

The record of the last meeting was read and approved.

Prof. Ira N. Hollis was elected a member of the Society.

The Chairman announced the death of Forrest L. Libbey, a member, which occurred July 21, 1894, and, on motion, it was voted to appoint a committee to prepare a memoir. The committee appointed, consisted of Messrs. Henry Manley, N. S. Brock and S. E. Tinkham.

The Secretary read a communication from the secretary of the Society of Civil Engineers of France, transmitting an official letter of thanks for the reception received by its delegates at the time of their trip to America. The Secretary stated that he had received from the same source a certain number of medals and drawings, souvenirs of the trip, one of each being designated for the Society, and the balance to be distributed among the members of the Society who took special part in the reception of the French Engineers.

On motion, the Secretary was directed to acknowledge the receipt of the communication and the gifts, and to convey to the Society of Civil Engineers of France the thanks of the Boston Society of Civil Engineers.

It was also voted to refer the distribution of the medals and drawings to the Board of Government with full power.

Professor Gaetano Lanza was then introduced, and gave an account of some of the results of recent experiments in testing materials in the Engineering Laboratories of the Massachusetts Institute of Technology. He spoke particularly of tests made on the riveted joints in the webs of plate girders, and exhibited several specimens of the joints tested. He also gave the results of some recent tests on the strength of timber.

A general discussion followed, in which Messrs. Dean, Snow and Parker took part.

Adjourned.

S. E. Tinkham, *Secretary.*

Charles W. Drake.—A Memoir.

By Edgar S. Dorr and Henry B. Wood, Committee of the Boston Society of Civil Engineers.

[Read February 21, 1894.]

Charles W. Drake was born July 28, 1848, in the city of Boston. After graduating from the English High School in 1866, he was appointed to a position with the City Surveyor, Mr. Thomas W. Davis, and in this he had for several years employment congenial to his tastes.

On December 22, 1886, he accepted what appeared to him a more promising position with the New York and New England Railroad. During the four years of his service with this company, a variety of work was intrusted to his care, embracing plan-making, the computation of earthwork, and monthly estimates, all of which was executed with a conscientious care and fidelity, characteristic of the deceased. His execution of this work inspired unbounded confidence.

Later he was employed in the West by the Ohio and Mississippi Railroad, but a change of plans in the management of this line soon brought this work to a close.

Early in 1891 he was appointed a draughtsman in the Street Department of the City of Boston, in which capacity he served until the time of his death, which occurred November 22, 1891.

Of his work in his latest occupation, we may say that he was a diligent and painstaking assistant, quietly seeking to know and to carry out the purposes of the orders given him and to arrange his results intelligently.

He was a man of extreme faithfulness, and always showed an interest in his work, ever striving for the contemplated resultant regardless of the hours of labor that it cost or the extent of the remuneration for his services.

Personally he was kind and amiable in his disposition, and while not, perhaps, as well known by his achievements as many others, he was most esteemed by those who knew him best, and he won the respect and friendship of all with whom he came in contact by the conscientiousness of his work and by his unfailing good temper and courtesy.

None ever questioned his integrity, or his freedom from all corrupting influence or motive, an attribute most essential to the good standing and success of all engaged in the engineering profession.

As one of our number has well said, "It is not given to all of us to be great engineers. It is given to us to be honest, straighforward, helpful men and to deserve the respect and affection of our brother engineers; and that kind of fame we may all strive for and obtain."

Engineers' Club of St. Louis.

402D MEETING, SEPTEMBER 19, 1894.—The club was called to order at 8.15 P.M., at 1600 Lucas Place, President Crosby in the chair and nine members present. The minutes of the 401st meeting were read and approved. The Executive Committee reported the doings of its 165th, 166th, 167th, 168th and 169th meetings. Mr. T. L. Condron having resigned as Librarian, the committee had appointed Mr. E. A. Hermann acting librarian. By consent, the election of Librarian was deferred until the next meeting.

An application for membership was announced from Mr. Chas. O. Fischer, secretary and treasurer of the Pitzman company of surveyors and engineers.

Mr. T. A. Meysenburg having presented the club with a copy of "The Lowell Hydraulic Experiments," by Francis, a vote of thanks was tendered him.

The President read a communication from the Société des Ingénieurs Civils de France, transmitting a vote of thanks for their entertainment last summer, together with a number of souvenirs and medals. The President appointed Mr. Edward Flad a committee of one to prepare a suitable form of acknowledgment, to be presented at the next meeting. It was also decided to defer until then any action regarding the distribution of the souvenirs.

Mr. E. A. Hermann then addressed the club on "Reconstruction and Improvement Work on Railroads," stating that nearly all roads, when constructed, pass through thinly settled country, affording little traffic. The certainty that only very small earnings are possible for a number of years, presents the alternative of a cheap and poorly built railroad, or none. Usually the former is chosen. Conse-

quently the new road, when opened for business, is, as a rule, barely substantial enough to permit the locomotive to pass over it at very moderate speed.

Before beginning construction, very little time is devoted to surveys. Under constant pressure to "build it cheap and whoop 'er up," errors in location are frequent. The line is full of curves, and the grade follows the general surface of the ground as nearly as possible, up hill and down, with little attempt to do more than mere surface scratching, and without regard to cost of operation. The track, trestles, bridges, depots, shops, etc., are as cheap as they can be made, but all this flimsy construction is justified, and, in fact, necessitated by the circumstances: the opening up of new country with little business in sight.

The best part of the new road is the rolling stock—locomotives with much fancy brass ornamentation, and gorgeously painted passenger cars. But this cheap splendor does not counterbalance the miserable construction of roadway and structures. With rapidly increasing traffic these soon begin to go to pieces, and the work of reconstruction follows as a disagreeable necessity. This generally begins with the renewal of the track ties, followed by that of trestles, bridges, rails, ballast, depots, shops, water tanks, and minor structures. Then comes a demand for extensive improvements: re-alinements for reducing curvatures and shortening the line, cutting down steep grades and raising depressions. The further rapid growth of traffic soon necessitates other improvements, notably side tracks and yards, double main track, interlocking signals at grade crossings, stone culverts, better bridges, heavier rails, stone ballast, better depots, warehouses, grain elevators, stock-yards, etc.

The improvement of the rolling stock follows rapidly after the first overhauling of the roadway, and then takes the lead, remaining far in advance; for the weight of locomotives and cars increases in a much more rapid ratio than the strength of track and of bridges. The interior finish of passenger cars has become an expensive luxury, and it is practiced most by those roads where it is considered cheaper to attract the traveling public by magnificent cars than by a substantial roadway. The grand luxury of the car is evident. Rotten ties and weak bridges are unseen. But experienced travelers are rapidly learning to discriminate in favor of the progressive railroads who provide a safe and substantial roadway on which the wheeled palaces can truthfully make good the claim set up by every railroad: safety, speed, and comfort.

The reconstruction and improvement of our railroads has progressed slowly but steadily. As a general rule, nothing is done until it is absolutely necessary; but then it is done quickly. A vast amount of reconstruction remains to be done. Its consummation is a question of development. Increase of traffic will necessitate more reconstruction and further improvements, and increased earnings will permit them to be carried out. Comparatively few of our railroads can be said to be more than half finished, and they never will be quite finished. When the work of reconstruction is believed to be completed, improvements will still be necessary.

The address was discussed by Messrs. Crosby, Eayrs, Flad, McCulloch, Curtis and Bryan. The unsatisfactory character of the present type of rail fastenings was mentioned. Some discussion was had on the welding of rails, but as yet the available data seems to be insufficient to serve as a satisfactory basis of opinion as to the merits of the system.

Adjourned. Wm. H. Bryan, *Secretary.*

Association of Engineering Societies.

Vol. XIII. October, 1894. No. 10.

PROCEEDINGS.

Western Society of Engineers.

319th Meeting, September 19, 1894.—The 319th meeting, an adjourned meeting, was held at Parlor 44, Grand Pacific Hotel, Chicago, at 8 p.m., September 19, 1894. Fifty-six members and guests present.

President Herr took the chair and called the meeting to order.

The President: The resolution offered at the last regular meeting was as follows:

" *Resolved*, That the recommendation of the Committee be concurred in, and that it be ordered that the Society withdraw from the Association of Engineering Societies, and that a vote on this resolution be taken at an adjourned meeting two weeks from to-night."

The resolution is before you. Before the discussion is taken up I will ask the Secretary to read a resolution passed by the Board of Directors at its meeting to-day. This resolution, I may say, was offered because it was considered that the Society did not understand the position that our Board took in the matter.

The Secretary then read the following:

In Board of Directors' meeting, September 19, 1894.

Resolved, That after further careful consideration of the report of the Committee on Publication recommending the withdrawal of this Society from the Association of Engineering Societies, and basing our opinion on the financial prospects of our Society and its future development on the present outline plans, we reiterate our former approval of the said report and advise the membership to adopt it.

After remarks by Messrs. Benezette Williams, Cregier, Hunt, Morehouse, Chanute and Randolph, the Secretary, at the request of the President, read a letter from Mr. John C. Trautwine, Jr., Secretary of the Association, dated Philadelphia, September 15th, in which he suggests that extra copies of the papers and proceedings of this Society can be struck off at the same time as printed for the Journal, and these extra copies can then be bound up together and issued at any interval desired, as the transactions of the Western Society of Engineers. The extra expense involved he thought would be small.

Further remarks were then made upon the question of withdrawal from the Association, by Messrs. Benezette Williams, Wallace, Hunt, Chanute, Roney, Barnes and Lundie.

Mr. Lundie then offered, as a substitute for the original motion, "that the

Secretary be instructed to serve notice of withdrawal of this Society from the Association of Engineering Societies, as a temporary expedient, and that a letter ballot be ordered to be canvassed at the October meeting."

After remarks by Messrs. Hunt, Cregier, Wallace, Chanute and Maddock, the latter suggested that the ballot be canvassed at the November meeting instead of the October meeting.

Further remarks were then made in discussion by Messrs. Goldmark, Randolph, Morehouse, Appleton and Benezette Williams. The latter gentleman offered, as an amendment to the substitute, that the vote be canvassed at the December meeting. The amendment was accepted by Mr. Lundie. The substitute then read "that the Secretary be instructed to serve notice of the withdrawal of this Society from the Association of Engineering Societies, as a temporary expedient, and that a letter ballot be ordered to be canvassed at the December meeting."

Motion seconded and carried unanimously.

Mr. Wallace then moved that a committee of two be appointed by the chair, one from among those who are in favor of remaining in the Association, and one from among those who are in favor of withdrawing, to assist the Secretary in preparing a statement of the question for submission to the members of the Society for letter ballot.

Motion seconded and carried.

The chair appointed, as such committee, Mr. Benezette Williams and Capt. Hunt.

A paper on "Strains and Deflections in Solid Bridge Floors," was then read by the author, Mr. Henry Goldmark.

After the reading of the paper several members took part in its discussion. Mr. Barnes moved that an abstract of the paper, with illustrations, be published with the proceedings of this meeting.

Motion seconded and carried.

Owing to the lateness of the hour and the fact that Mr. Bates had retired from the meeting, his paper on "A Broken Pinion Shaft," was laid over to the next meeting.

On motion the meeting adjourned.

THOS. APPLETON, *Secretary.*

320TH MEETING, OCTOBER 3, 1894.—The 320th meeting was held at Parlor 44, Grand Pacific Hotel, Chicago, at 8 P.M., October 3, 1894. Ninety-one members and guests present.

President Herr took the chair and called the meeting to order.

The minutes of the previous meeting were approved as printed.

The Secretary then read the report of the Board of Directors as follows:

At the meeting held September 19th, a bill of $41.67 was approved and ordered paid from the special fund.

At the meeting held October 3d, the Secretary reported cash on hand, $325.65 of which $21.33 is in the special fund and $15.10 in the library fund. Bills amounting to $128.75 were approved and ordered paid out of the general fund.

The following additions have been made to the Library and Reading Room: 82 volumes, including 17 volumes of transactions of technical societies, 6 volumes of maps, 69 numbers of transactions, 6 volumes of periodicals (unbound), 375 numbers of periodicals, 77 pamphlets, 1 chart, 23 bulletins, and subscriptions to 9 technical journals.

The report of the Board of Directors was, upon motion, received and placed on file.

9 candidates for membership were elected. 15 applications for membership, 16 applications for associate membership and 2 applications for junior membership were received and placed on file.

There being no reports of committees, the President asked if there was any new business.

Mr. Rossiter: About three or four weeks ago the Architects of Chicago appointed a committee to look after the buildings and different improvements for beautifying the city. They also asked two or three other societies to join with them for the same purpose. While our Society has not been asked to join, I would like to see a committee of this Society appointed to act with them. I think they anticipate some action regarding the filling in of the lake front for park purposes—perhaps locating the post-office and court-house there. I would like to see a committee of three or five appointed from this Society to co-operate with those from the other societies.

After remarks by Messrs. Artingstall and Cooley, the latter moved that the subject-matter be referred to the Board of Directors for consideration and recommendation.

Motion seconded and carried.

The Secretary then read a paper entitled, "Notes on a Broken Pinion Shaft," by Mr. Onward Bates. The paper was illustrated by photographs showing a peculiar fracture of a wrought-iron shaft used in swinging a railroad drawbridge.

Messrs. Goldmark, Finley and Artingstall took part in the discussion of the paper.

Mr. T. T. Johnston then read a paper entitled, "General Hydraulics of the Chicago Main Drainage Channel."

The paper treated of the grade and cross-section of the channel; its effect on the great lakes; the effect of the Des Plaines River; its effect on the Illinois and Mississippi Rivers, etc. It was copiously illustrated by large maps and diagrams.

The paper was discussed by Messrs. Rossiter, Cooley and W. E. Williams.

It is expected that both papers, with the discussions, will be printed later.

After the discussion of Mr. Johnston's paper, the President suggested that owing to the lateness of the hour the discussion of the paper read at the last meeting by Mr. Goldmark be postponed to the next meeting.

On motion, duly seconded, the meeting adjourned.

Thos. Appleton, *Secretary.*

Civil Engineers' Society of St. Paul.

October 1, 1894.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.20 p.m.; eight members and one visitor present.

A circular communication from Mr. E. L. Corthell, dated July 7, 1894, proposing an International Association of Engineers and Architects, was referred to Mr. Estabrook and Mr. Hilyard as a committee of consideration. A letter from Mr. O. Chanute, transmitting a medal, a lithograph, and two reports of the French Society of Civil Engineers, in commemoration of the visit of its members to America in 1893, was placed on file, and the accompanying souvenirs were accepted.

Mr. Oliver Crosby was elected a member.

Printed copies of Mr. Woodman's paper on "Transition Curves" having been distributed among the members a week or two before the meeting, the author opened the discussion by briefly stating his reasons for preparing the paper, and afterward reviewed the somewhat complex work of Mr. C. L. Crandall. Other members spoke of personal experience with the casement curve, and several letters on the subject were read. It was decided that the discussion should be continued at the November meeting, that the various recitals should be put in writing, and that the resulting matter should be arranged for publication by Mr. Woodman and the Secretary.

Adjourned at 10.30 P.M.

C. L. ANNAN, *Secretary.*

Engineers' Club of St. Louis.

403D MEETING, OCTOBER 3, 1894.—President Crosby called the club to order at 8.25 P.M., at 1600 Lucas Place, there being twenty-one members and eight visitors present.

The minutes of the 402d meeting were read and approved. The Executive Committee reported the doings of its 170th meeting, at which the resignation of Mr. H. A. Wahlert had been accepted, and Messrs. Wellington Adams, A. A. Baldwin and A. L. Sieghortner, Jr., had been dropped from the rolls for non-payment of dues.

The application for membership of Mr. Charles O. Fisher having been approved, he was balloted for and elected. An application for membership was announced from Mr. Walter J. Sherman, contracting engineer for the Toledo Bridge Company.

Mr. Edward Flad presented the following, which was adopted unanimously:

Resolved, That the Engineers' Club of St. Louis appreciates most highly the courtesies extended by the Society of Civil Engineers of France, and hopes for a continuance of the pleasant relations so auspiciously inaugurated at the time of the visit of their delegates to St. Louis.

On motion it was ordered that the disposition of the medals and souvenirs from the French engineers be left in the hands of the Executive Committee.

The election of a librarian being then taken up, Mr. E. A. Hermann was chosen by a unanimous ballot.

Prof. J. B. Johnson tendered the club the back files for several years of some two dozen leading engineering journals, and stated that they would reach the club regularly in the future.

On motion the offer was accepted, and it was ordered that a vote of thanks be extended to Prof. Johnson.

Mr. N. W. Eayrs then described informally the power-house of the New Union Station, located about 1,800 feet south of the head house. The steam plant consists of four 250-horse-power Babcock & Wilcox boilers, set with revolving chain grates. The latter cost $1,000 per boiler, and proved entirely satisfactory, particularly in abating the smoke. The steam is used to operate three Buckeye tandem compound engines and two air compressors. The engines are directly connected to Siemens-Halske generators, which operate at 500 volts, and whose output is distributed by the five-wire system, permitting the operation of both arc and incandescent lamps. The compressors furnish air for the interlocking plant, which is the largest in the country, and with which 240 train movements were recently made in a single hour.

The station is heated from this plant, the pipes being laid in a conduit about 1,800 feet long. The indirect system is used in the main building. Air is taken in at the top of the tower by two fans in the sub-cellar and passed over steam coils. Each fan is driven by a 40-horse-power motor. Direct radiation is used in the offices.

Discussion followed by Messrs. Tausig, Bryan and Kinealy.

Mr. J. A. Laird then presented the results of the experiments recently conducted by the water department to determine the efficiency of various forms of steam pipe covering. Chemical analyses were first made of each covering. Tests were then made—first, by noting the condensation per hour in a 10-foot length of 1-inch pipe, to which a covering 1 inch thick had been applied; and, second, by filling the same pipe with steam, and, after closing all valves, noting the time which elapsed before the pressure gage fell to zero. The first test resulted as follows:

	Cubic Centimeters.
Magnesia, plastic	334
" sectional	335
Asbestos fire felt	367
" sponge moulded	371.3
Plaster of Paris and sawdust	438
Asbestos sponge cement	604.5
The bare pipe	1085.

The second test confirmed these figures. The initial steam pressure was thirty pounds.

Prof. Kinealy called attention to the fact that these experiments agreed well with previous investigations, which had shown that the best coverings reduced the condensation to about one-third that in the bare pipe.

Adjourned. WM. H. BRYAN, *Secretary.*

404TH MEETING, OCTOBER 17, 1894.—The Club was called to order at 8.15 P.M. by President Crosby, at 1600 Lucas Place. Twenty-two members and seven visitors present. The minutes of the 403d meeting were read and approved. The President appointed Mr. Julius Baier a member of the Committee on Library, to fill the vacancy occasioned by the removal from the city of Mr. T. L. Condron.

Prof. Chas. C. Brown then addressed the Club on "A New Method of Determining Sewage Pollution of Water." The Professor had given the subject a great deal of thought while engineer of the State Board of Health of New York, making a number of examinations of the waters of the Mohawk and Hudson Rivers, and later of Mississippi River water in the St. Louis settling basins. All the features bearing upon the pollution of water had been studied, such as the geology, meteorology, population and sources of pollution. The effect of the various causes of pollution had been considered: *first*, chemically; and *second*, biologically, to determine the changes in the number and kinds of bacteria. He showed that population increases much faster in the cities and villages than in the rural districts, and that the large cities and villages are, as a rule, situated on or near large rivers. From this it follows that the pollution of rivers by sewage increases faster than the population itself. Prof. Brown explained how the samples were taken, and showed the construction of the fermentation tube, which was first suggested by Dr. Theodore Smith, of Washington, D. C., and which had for its object the separation of the gas-producing bacilli. The results were quite satisfactory, although the process still falls short of perfection, and much still remains to be done before definite and positive results can be had. The subject was discussed by Messrs. Seddon, Holman, Johnson and Jewett and by Drs. Green, Ravold and Homan.

Adjourned. WM. H. BRYAN, *Secretary.*

Engineers' Club of Cleveland.

Rooms of the Cleveland Electric Club, October 9, 1894.—The meeting was called to order at 7.50 p.m. by the Vice-President. Forty-six members and visitors were present. The report of the meeting of September 11th was read and approved.

Applications for active membership were read from Messrs. Frederick C. Phillips and E. S. W. Moore. A letter was read from Mr. O. Chanute, transmitting a medal, souvenir lithographs and reports of the delegation of French engineers which visited the United States during the World's Columbian Exposition. A letter was read from Messrs. Riehlé Bros., transmitting copies of their catalogue of testing machinery.

The question of permanent quarters for the club was taken up and discussed by Messrs. W. H. Searles, C. W. Wason and E. P. Roberts.

Lieut.-Col. Jared A. Smith then read the paper of the evening on the "Construction of a Sea Wall at Fort Taylor, Key West, Florida." The paper was discussed by Messrs. H. C. Thompson, C. G. Force and W. H. Searles.

Following this paper there was an informal discussion on the subject of the "Improvement of the Cuyahoga River and Harbor."

The meeting adjourned at 9.45 p.m.

Frank C. Osborn, *Secretary.*

Boston Society of Civil Engineers.

October 17, 1894.—A regular meeting of the Boston Society of Civil Engineers was held at its rooms, 36 Bromfield Street, at 7.50 o'clock p.m., President W. E. McClintock in the chair. Seventy-six members and visitors present.

The record of the last meeeing was read and approved.

Mr. Walter C. Stevens was elected a member of the Society.

On motion of Mr. Winslow the thanks of the Society were voted to the Boston Water Board for its kindness in furnishing railroad transportation on the occasion of the visit of the members of the Society to Basin V on September 26, 1894.

The Secretary read a circular letter from Mr. E. L. Corthell submitting a proposition for the organization of an International Institute of Engineers and Architects. On motion of Mr. Noyes the communication was referred to the Board of Government.

Mr. Spencer Miller, Chief Engineer of the Lidgerwood Manufacturing Co., was then introduced, and read a very interesting paper on cableways.

The paper was fully illustrated by a large number of stereopticon views. After passing a vote of thanks to Mr. Miller, the Society adjourned.

S. E. Tinkham, *Secretary.*

Association of Engineering Societies.

Vol. XIII. NOVEMBER, 1894. No. 11.

PROCEEDINGS.

Montana Society of Civil Engineers.

Butte, Mont., October 13, 1894.—Regular Monthly Meeting.—The meeting convened at the office of Messrs. Harper & Baker, at 1.30 P.M., President Haven in the chair.

There were present Messrs. Cumming, Smith, Haven, Wheeler and Whitcomb of Helena, and Messrs. Harper, Baker, Gutelius, Goodale and two visitors, of Butte.

It was decided to adjourn the business meeting until 7.30 P.M., and to go at once to visit some of the mines and mills in the vicinity of Meaderville.

The Society then visited the Leonard Shaft and examined the Riedler Pump and the steam hoist, both of which were very favorably commented upon by all present. It was the unanimous opinion that the Riedler Pump was performing in a very satisfactory manner the work assigned it, and that it was probably superior to any other pump known to the party for mining purposes.

Next was visited the concentrator belonging to the Butte and Boston Company. The party spent considerable time examining the machinery, and was taken from there to see the Brown, Allen and O'Harrah furnaces. These furnaces have been improved by Mr. Allen, the manager of the works, so that they are working in a very satisfactory manner.

The party next visited the converting plant of the Montana Ore Purchasing Company. In this plant, copper mat 50 per cent. to 55 per cent. pure, is converted into copper bars 99.3 per cent. pure copper, by oxidizing iron and sulphur present in the mat, and leaving the nearly pure copper as a product.

7.30 P.M.—The business meeting was called to order at 7.30 P.M., at the office of Messrs. Harper & Baker.

The minutes of the last meeting were read and approved.

The applications of Messrs. Gustave A. Kornberg and Archibald W. Mahon, having been approved by the trustees, were read, and the Secretary was instructed to issue letter-ballots to the members, to be opened at the November meeting.

The applications of Messrs. Eugene Carroll, Walter W. Pennington, Robert A. McArthur, Malcolm L. McDonald and James Breen, of Butte, and of Mr. James H. Henley, of Helena, for membership, were submitted and were referred to the trustees.

The special committee on County Surveyors was instructed to prepare a bill, defining the duties and compensation of County Surveyors of the State of Montana, to be submitted to the Society for discussion at the November meeting.

The Secretary was instructed to request Prof. Ryon, the chairman of the special committee on irrigation, to report, at the next monthly meeting, the result of his experiments in reference to the measurement of water; and also to submit a bill to be placed before the legislature of Montana during the coming winter.

The committee on the DeLacy memorial was requested to make a report at the next meeting.

On motion of Mr. Harper, duly seconded, the President and Secretary of the Society were instructed to prepare and have printed a form of application for membership in this Society.

A letter from Mr. Chanute was read, forwarding a souvenir lithograph and report of the French Society of Civil Engineers, commemorating the visit of members of that society to the Columbian Exposition, and thanking the associated Engineering Societies for the courtesy extended to them while there.

It was moved and seconded that a vote of thanks be awarded to the Great Northern, Northern Pacific and Union Pacific Railways for the courtesy extended in the matter of transportation to and from the meeting; also to Messrs. C. H. Palmer, General Manager, C. M. Allen and J. H. Vivian, Superintendents of the Butte and Boston Co.; to Mr. James Breen, Superintendent of the Montana Ore Purchasing Co., for his courtesy in extending an invitation to the Society to visit the company's works, and for their kindness in accompanying the party and explaining the working of the machinery, etc, and also to Mr. Eugene Carroll for his invitation to visit the Butte City Water Works, and to Mr. Charles W. Goodale for an invitation to visit the Gagnon Mine.

No other business offering, the meeting adjourned.

The party then accompanied Mr. Goodale to visit the Gagnon Mine. They examined the different levels, the large Knowles Pump and other features, including the hoist, ore bins, etc., connected with the property.

BUTTE, OCTOBER 14, 1894.—At 8.30 A.M. the party accompanied Mr. Carroll to examine the Butte City Water Works. They were taken to the site of the reservoir which is now being constructed, and were very pleasantly entertained by Mr. Carroll, who explained the method of constructing the reservoir, and the difficulties experienced in connection with the work.

The dam is to be a solid masonry structure 100 feet high, of which about 40 feet are already constructed.

G. O. FOSS, *Secretary.*

Minutes approved by meeting of Society, November 10, 1894.

W. A. HAVEN, *President.*

NOVEMBER 10, 1894.—The regular monthly meeting of the Montana Society of Civil Engineers was held at the office of Messrs. Sizer & Keerl. There were present: Members, Messrs. McNeill, McRae, Relf, Kelly, Haven, Hovey and Keerl and a number of visitors. President W. A. Haven occupied the chair. The minutes of the meeting held at Butte, October 13th, were read and approved. This

was followed by the second reading of the application of the following engineers for membership in the Society: Messrs. Eugene Carroll, James Henry Hensley, Malcolm McDonald, Walter W. Pennington and Robert A. McArthur. Ballots for membership for Archibald W. Mahon, of Glasgow, and Gustave A. Kornberg, of Butte, were canvassed and both were declared elected.

The Committee on County Surveyors submitted a report in the form of an amendment to the present statute, providing that the expenses of County Surveyors should be paid while they are on duty on surveys. Mr. McNeill read a report on a proposed change in the road laws, by which the County Surveyors would have charge of highways and highway bridges. These changes would be in the line of economy, efficiency and good roads. Considerable correspondence on the subject between Mr. McNeill and other County Surveyors was read. After a full discussion it was voted to refer the reports and the whole matter to a select committee of three members of the Society, with instructions to report at the December meeting in the form of a bill to be presented, after further action of the Society, to the next Legislature, covering all the points referred to. The names of the Committee will be announced hereafter.

Prof. A. M. Ryon, of the College of Agriculture and Mechanic Arts at Bozeman, who at the last annual meeting was appointed a committee to experiment and report upon a more exact method of determining what is meant by a "miners' inch" under the statute of Montana, made a very full and instructive report. It covered the ground thoroughly and demonstrated the unsatisfactory and uncertain results to be obtained by attempting to follow the present law. It was voted that Prof. Ryon be continued as the Committee on the Measurement of Water, and that he be requested to draft a bill on the subject, to be read at the next meeting of the Society, so that it may be discussed by the members, and got ready to present to the next Legislature. It was also voted to print 100 copies of the report for the use of the members of the Society and others interested in the matter.

A letter from Prof. Ryon was read, stating that the Committee on "the Appropriation of Water" was not ready to report.

The meeting then adjourned. G. O. Foss, *Secretary.*

Civil Engineers' Society of St. Paul.

NOVEMBER 5, 1894.—A regular meeting of the Civil Engineers' Society of St. Paul was held Monday, November 5, 1894, at 8 P.M. Twelve members and five visitors were present.

A resolution was passed thanking President F. W. Cappelen, of the Engineers' Club of Minneapolis for courtesies extended on the occasion of the Sault Ste. Marie excursion, October 20, 1894.

Mr. Charles A. Alderman was elected to membership. The discussion of the subject of "Transition Curves," introduced at the last meeting, was continued by the reading of several letters from engineers in various parts of the country, and by an hour's general discussion, the substance of which will be prepared for publication.

At the request of President Wilson, Prof. W. R. Hoag outlined the present relations between the Minnesota State University, the United States Coast and Geodetic Survey and the United States Geological Survey touching the geological and topographical survey of the State.

Pending an adjustment in December next of a rather unsettled state of affairs in this matter of interest to engineers and citizens generally, a committee, consisting of Mr. Hilgard, Mr. Woodman and Mr. Stevens, was appointed to examine the facts in detail and to report at the next meeting.

Mr. Louis Dunn then exhibited ingenious models of safety devices for switches.

Adjourned at 10.30 P.M. C. L. ANNAN, *Secretary.*

Western Society of Engineers.

321ST MEETING, NOVEMBER 7, 1894.—The 321st meeting was held at Parlor 44, Grand Pacific Hotel, Chicago, at 8 P.M., November 7, 1894. Fifty-six members and guests present.

President Herr took the chair and called the meeting to order.

The minutes of the last meeting, as printed, were approved.

The Secretary read the report of the Board of Directors.

At the meeting of the Board held October 17th, the following applications for membership were received and placed on file:

As members—Charles E. Davis, E. E. Johnson and J. L. Pilling. As associates—H. P. Mason, T. W. Snow and George Staunton, Jr.

At the meeting held November 7th the following applications for membership were received and placed on file:

As members—P. H. Ashmead, H. P. Boardman, Frank E. Brown, Wm. F. Dennis, F. B. Knight, Wm. F. Merrill, John Stumpf, John M. Witherspoon and Erwin E. Wood. As associates—Arthur E. Bingham, Charles E. Marsh, R. S. Walsh and E. L. Williamson.

The following gentlemen were elected to membership:

As members—Edward J. Blake, T. L. Condron, Chicago; P. H. Connolley, Riverside, Ill.; Howard N. Elmer, Frank W. Forbes, Wm. H. Finley, Frank C. Hatch, Willis B. Hayes, Geo. T. Horton, Daniel H. Lawton, John A. Moody, Geo. P. Nichols, E. L. Ransome, E. M. Robinson and George H. Scott, all of Chicago. As associates—William Boldenweck, Frederick Braasch, Thomas Byrne, J. S. Dunham, B. A. Eckhart, Thomas Gahan, A. P. Gilmore, John Griffiths, Lionel Jacobi, Thomas Kelly, A. McArthur, M. McDermott, Peter W. Neu, Joseph Pajeau, Wm. H. Russell and Frank Wenter, all of Chicago. As juniors—Henry W. Lee and Charles A. Ring, both of Chicago.

The Librarian reports total accessions to the Library for the month of October as follows: Fifty-three volumes, 22 pamphlets, 5 volumes of periodicals, 22 numbers of periodicals, 5 photographs, 3 framed photographs, 35 bulletins, 1 plan (4 sheets), 1 set specifications, 1 map, 1 chart and a collection of trade catalogues and trade directories.

THE PRESIDENT: The report of the Board of Directors will be received and placed on file.

The Secretary reported with regret the death of Mr. Joseph P. Card, member of this Society, which occurred October 22d.

The Secretary also reported that in accordance with the action of the Society at a previous meeting, he mailed the following letter to the Chairman and Secretary of the Association of Engineering Societies:

"51 Lakeside Building, Chicago, September 25, 1894.

Dear Sir:—At the last meeting of this Society it was voted that the Secretary serve notice of the withdrawal of this Society from the Association of Engineering Societies, said withdrawal to take effect at the close of the present year.

Yours truly,

Thos. Appleton, *Secretary.*"

The receipt of this letter prior to September 30th was acknowledged by Messrs. J. B. Johnson, Chairman, and John C. Trautwine, Jr., Secretary, of the Association of Engineering Societies.

The Secretary then read a circular letter from Mr. Trautwine, dated October 26th, and setting forth the advantages to engineering societies to be derived from joining the Association of Engineering Societies.

President Herr: The Chair understands that this letter was simply meant to be read to the members, that they might be influenced possibly in their letter-ballot on that subject, and that no further action of the Society as a society is necessary.

It was moved that a committee of three be appointed to prepare a memoir of the late Mr. Carr.

The Chair appointed Messrs. Chanute, Hunt and Strobel as such committee.

A paper from Mr. Corthell, in reference to forming an International Engineering Institute, was passed around among the members present.

Mr. E. F. Osborne read a paper on "Refrigeration by Carbon Dioxide."

The paper was a full exposition of the mechanical features of artificial refrigeration by the use of this gas, and illustrations of apparatus and fittings were given by lantern slides.

At the close of the paper, 11.15 P.M., after a vote of thanks to Mr. Osborne, the meeting adjourned. The continuation of the discussion of the paper on "Solid Bridge Floors" is therefore postponed to the next meeting.

Thos. Appleton, *Secretary.*

Engineers' Club of St. Louis.

November 7, 1894, 405th Meeting.—The Club met at 8.20 P.M. at 1600 Lucas Place. Vice-President Russell in the chair and seventeen members and seven visitors present. The minutes of the 404th meeting were read and approved. The Executive Committee reported the doings of its 171st meeting, approving the application for membership of Walter J. Sherman. He was balloted for and elected.

Mr. Edward Flad introduced the following resolution and moved its adoption:

Resolved, That a committee of ten be appointed by the Chair to report to the Club a schedule of the customary charges made by engineers for services rendered either for consultation or expert work, reports, plans and specifications, etc., or for services by the month or year, with a view to establishing a record of the usual and limiting charges customary, rather than a proper schedule of charges. The Chairman to be a member of the Committee.

After discussion by Messrs. H. A. Wheeler, Philip Moore, E. Flad, W. H. Bryan, J. A. Ockerson, J. B. Johnson and S. B. Russell, the motion was carried. The Chair appointed the following Committee: E. Flad, J. B. Johnson, H. A. Wheeler, M. L. Holman, J. A. Ockerson, W. B. Potter, E. D. Meier, J. Pitzman, W. H. Bryan and S. B. Russell.

Professor H. A. Wheeler then read a paper on "The Merz Process of Handling Garbage at the South St. Louis Works."

Previous to 1891 the garbage had been dumped in the river, the quantity then being estimated at 40 tons per day. It now averages 150 tons daily, and has reached 300 on Mondays during the watermelon season, the daily quantity per capita varying between one-third and one pound. All garbage is now reduced by the St. Louis Sanitary Company, the city paying them 9 cents per 100 pounds up to 100 tons daily, above which quantity it is reduced free of charge. The upper, or No. 1 plant, built four years ago, was originally of 40 tons capacity; it was later increased to 75, and last summer handled as high as 100 tons. The No. 2 plant at the foot of Chouteau Avenue was only temporary and has been abandoned. The No. 3 plant is located at the foot of Montana Street in South St. Louis, and began operations in the spring of 1894. Its daily capacity is 200 tons. Professor Wheeler explained in detail the system employed, devoting special attention to the methods of ventilation. In his opinion the plant was of great interest to engineers, and deserved the good opinion of the profession as representing an intelligent effort in the direction of a solution of a most difficult problem.

The discussion was participated in by Messrs. Johnson, Judson, Wise, Hermann and Chauvenet. Adjourned.

WM. H. BRYAN, *Secretary.*

406TH MEETING, NOVEMBER 21, 1894.—President Crosby called the Club to order at 8.15 P.M., at 1600 Lucas Place, with twenty-five members and eight visitors present. The minutes of the 405th meeting were read and approved as corrected. An application for membership was announced from Mr. A. W. Morrell, electrical and mechanical engineer of the Lindell Railway Company.

It was on motion ordered that a committee of three be selected by ballot to make nominations for officers for 1895, reporting at the next meeting. On balloting, Messrs. C. M. Woodward, J. B. Johnson and Robert Moore were chosen.

The Committee on Library submitted a subscription list in the following form, with a request for signatures:

We, the undersigned, hereby agree to pay annually the sums set opposite our names, each for himself, to the Treasurer of the Engineers' Club of St. Louis for the term of five years, for the purpose of forming a Library Fund of $150 per annum.

It is distinctly understood, however, that no call for payment is to be made from this subscription if the ordinary revenues of the Club shall enable it to appropriate the above-named sum each year for the library, and that the Club shall first appropriate as large a sum as can be furnished from its ordinary revenue for this purpose; any deficiency in such appropriation to be made good by a pro-rata call from the undersigned guarantors.

Prof. C. M. Woodward then read his address on "The Relation of Technical to Liberal Education," explaining that the paper had originally been delivered before the Council of Education, a body of sixty teachers. The paper first defined at some length the terms "Technical" and "Liberal" as used in this discussion. The work of the civil engineer, the mechanical engineer, the electrical engineer, the architect and the chemical engineer were clearly pointed out. The prominent features of a liberal education, both as it formerly existed and as it is now modified by the widespread system of electives, was pointed out. The importance of the many new elements in education was explained. The best technical and liberal trainings nowadays cover much the same ground. The Professor paid a glowing

tribute to the dignity of the engineer, and defined the true relation of technical to liberal education, as "liberty, fraternity and equality."

Prof. H. A. Wheeler reported the results of a recent visit to Cincinnati, where he had gone to examine the Simanoin desiccation process for the reduction of garbage. He explained the system in detail and compared it with the Merz system, from which it differed principally in that the desiccation and oil extraction were carried on in the same tank, instead of in separate vessels. He considered the process inferior to the Merz, both in its practical operation as shown in Cincinnati and in the principles underlying its use.

Adjourned. WM. H. BRYAN, *Secretary.*

Civil Engineers' Club of Cleveland.

ROOMS OF THE ELECTRIC CLUB, CLEVELAND, OHIO, NOVEMBER 13, 1894.—The meeting was called to order at 8 P.M. by the Vice-President. Twenty members and visitors were present. The minutes of the meeting of October 9th were read and approved. The Vice-President appointed Messrs. A. H. Porter and James Ritchie tellers for the evening. Mr. Wason, in behalf of the Executive Board, reported in favor of transferring Mr. C. W. Foote from active to corresponding membership.

Application for active membership from Mr. Harry S. Nelson was read. A letter from Mr. John C. Trautwine, Jr., Secretary of the Association of Engineering Societies, in regard to the percentage of receipts from advertisements reverting to the Club, was read. Mr. Bowler moved to accept and place on file. Seconded by Mr. Wason and passed.

Mr. Wason reported for the Committee on Quarters and requested an expression of the sentiment of the Club in regard to the advisability of joining with other similar organizations in securing quarters for joint use. The question was discussed by Messrs. Hosea Paul, Herman, Searles, Porter and Ritchie. Mr. Searles moved that the Committee on Quarters be continued and further empowered to confer with other societies in regard to the securing of joint quarters, and requested to report at the next meeting, stating what societies would be likely to join with us. Seconded by Mr. Ritchie and passed. Mr. Luther Allen stated that it was probable that the new Chamber of Commerce Building would be built, that it would probably be completed about the middle of 1896, and that possibly the Club could then secure permanent quarters there. Mr. Wason suggested that arrangements might be made to join in the use of quarters with the Electric Club of Cleveland for the present. Mr. Searles offered a few remarks on the advisability of joining with other clubs, suggesting that, if possible, the Club have quarters of its own.

The tellers announced through the Secretary the election to active membership of Messrs. Frederick C. Phillips and E. S. W. Moore.

The memorial of Cyrus P. Leland was read by Mr. E. A. Handy. Mr. Searles and Mr. Porter added a few further remarks of personal recollection of Mr. Leland and his connection with the Club. Mr. Searles moved that the report be accepted and spread upon the records, and that a copy of the same be forwarded to the family. Seconded by Messrs. Richardson and Bowler, and passed. The paper of the evening, entitled "Classification by Numbers," was then read by Mr. Hosea Paul, and proved most interesting. The subject was discussed by Messrs. Herman, Searles, Barber, Ritchie and Paul. The meeting adjourned at 10 o'clock.

A. LINCOLN HYDE, *Secretary pro tem.*

Cyrus Powers Leland.—A Memorial.

By E. A. Handy, Luther Allen and Wm. H. Searles, Committee of the Civil Engineers' Club of Cleveland.

The Civil Engineers' Club of Cleveland, fully realizing the great loss it has sustained in the death of Cyrus Powers Leland, an active and honored member, desires to record this tribute to his memory.

Gifted with a brilliant mind and a kindly heart, he made warm and lasting friendships and won the affection of those who best knew him. In the routine of his daily life—and he was a faithful, honest, conscientious worker—next after his duty to the great corporation whose trusted official he was, came his interest in the welfare and success of this Club. As a working member and its Treasurer, he gave it his earnest and cordial support. The papers prepared by him and read before this Club, replete with valuable information and statistics collated with great care and judgment, are among its most valued records.

Upon those annual occasions when this Club met together for social recreation, no banquet seemed complete without a speech, wise and witty, from him whose voice is now hushed forever, and upon each recurring midsummer outing his cheery presence always brought sunshine. Possessing a vividly keen sense of the humorous and a retentive memory, his every-day converse was punctuated with story and repartee, incisive yet kindly.

His imposing presence was an index to the nobility of his character which other men might well admire. He lived a manly, useful, honest life, and then yielded it to his Creator bravely, as becomes a Christian.

Boston Society of Civil Engineers.

November 21, 1894.—A regular meeting of the Boston Society of Civil Engineers was held at its rooms, 36 Bromfield Street, at 8 o'clock P.M., President W. E. McClintock in the chair. Seventy-four members and visitors present.

The record of the last meeting was read and approved.

Messrs. David Hinckley and Morris Knowles were elected members of the Society.

The Board of Government was authorized to invest the permanent fund now in the hands of the Treasurer.

On motion of Mr. Wood, the thanks of the Society were voted to the Boston and Maine Railroad Company and to the Lowell and Suburban Street Railway Company for transportation furnished to the members of the Society, on the occasion of the excursion to Lowell.

Mr. Bryant brought before the Society the desirability of changing its rooms, so as to provide larger and better accommodations. After an explanation by the Treasurer of the amount of rent which was now paid, and of the increase which we should probably be obliged to meet soon, it was voted to refer the matter, with full power, to the Board of Government and the Committee on Headquarters, jointly.

Mr. Allen Hazen was then introduced, and read a very instructive paper entitled "Notes on European Water Supplies."

Prof. Thomas M. Drown followed with an account of the Lake Vyrnwy Water Supply for Liverpool.

A discussion followed, in which Prof. Sedgwick and Messrs. Fitzgerald and Hazen took part.

After passing a vote of thanks to Mr. Hazen, the Society adjourned.

S. E. Tinkham, *Secretary.*

ASSOCIATION
OF
ENGINEERING SOCIETIES.

VOL. XIII. DECEMBER, 1894. NO. 12.

PROCEEDINGS.

Civil Engineers' Society of St. Paul.

DECEMBER 3, 1894.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 6.20 P.M., on Monday, December 3, 1894. Twelve members and three visitors present. Vice-President Estabrook in the chair.

The minutes of the previous meeting were read and approved.

The Committee on Mr. Corthell's Prospectus for an International Institute of Engineers and Architects reported adversely, and the report was accepted and adopted.

The Committee on the State Survey asked for further time, which was granted.

The Librarian was instructed to ascertain the cost of the bound volumes necessary to complete the library files of the *Transactions of the American Society of Civil Engineers* and the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, and, after consulting the Treasurer, to report at the next meeting as to the advisability of purchasing the same at this time.

The Librarian was further instructed to inquire as to the availability of certain technical periodicals offered the Society by officers of the "Omaha" railroad, and to report at the next meeting.

Mr. J. H. Armstrong introduced the subject of Riparian Ownership of Lands Bordering on Lakes and Rivers, and showed the incompleteness of the United States laws touching the same. He suggested that in the case of rivers riparian rights should extend to a line midway between the meander lines, instead of to the ever-changing channel. Quoting from Justice Miller's Supreme Court decision of 1890, he explained the inadequacy of the present law. In the case of lakes, the element of the shifting channel is eliminated, and the legal center of the lake is the line midway between the meander lines, but the determination of the side boundary lines of each riparian owner is a matter concerning which there may be various opinions. This was brought out in general discussion of certain riparian divisions submitted by Mr. Armstrong, to whom a vote of thanks was given for his entertaining presentation of the subject.

Mr. C. A. Alderman stated that at Eau Claire, Wis., extensive encroachments have been made by private parties within the meander lines of the Chippewa and Eau Claire rivers, but that the municipality, notwithstanding much agitation by individuals, has as yet taken no steps to correct this.

Adjourned at 10.45 P.M.

C. L. ANNAN, *Secretary*.

Western Society of Engineers.

322D MEETING, DECEMBER 5, 1894.—The 322d meeting was held at Parlor 44, Grand Pacific Hotel, Chicago, at 8 P.M. Fifty-four members and guests present.

President Herr took the chair and called the meeting to order.

The minutes of the last meeting were approved as printed.

The Secretary read the report of the Board of Directors.

At the meeting of the Board of Directors held this afternoon the following gentlemen were elected to membership:

As Members—P. H. Ashmead, H. P. Boardman, Frank E. Brown, Charles E. Davis, Wm. F. Dennis, E. E. Johnson, F. B. Knight, Wm. F. Merrill, J. L. Pilling, John Stumpf, John M. Witherspoon, and Erwin E. Wood.

As Associates—Arthur E. Bingham, Charles E. Marsh, H. P. Mason, T. W. Snow, George Stannton, Jr., R. S. Walsh and E. L. Williamson.

The following applications for membership were received and placed on file:

As Members—W. I. Babcock, Howard A. Coombs, Charles W. Hotchkiss, John C. Nickson, Edwin C. Reynolds, Charles H. Wilson, H. F. J. Porter and Wm. C. Stearns.*

As Associates—Charles E. Schauffler and O. H. Vehmeyer.

It was moved by Mr. Reynolds that the ballots on the question of withdrawing from the Association of Engineering Societies be canvassed. Carried.

The Chair appointed, as tellers, Messrs. Reynolds, Modjeski and Goldmark; Mr. Benezette Williams was at first appointed, but asked to be excused from acting.

A memoir of Mr. Joseph P. Card was read by Mr. Chanute, Chairman of the Committee. This memoir is appended to these proceedings.

The tellers, having completed the count of ballots on the question of withdrawal from the Association of Engineering Societies, reported the result as follows:

In favor of withdrawal, 70; against withdrawal, 137.

The discussion of Mr. Goldmark's paper on Solid Floors for Railroad Bridges, was then taken up. Messrs. Horton, W. R. Roberts, Alvord, Finley, L. H. Evans, Graham and Goldmark participated.

As it is expected that the paper and discussion will be printed in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, no report of it will be attempted in these proceedings.

Upon the close of the discussion, the meeting adjourned.

THOS. APPLETON, *Secretary.*

Engineers' Club of St. Louis.

407TH MEETING, DECEMBER 5, 1894.—The annual meeting was called to order by President Crosby at 8.15 P.M., at 1600 Lucas Place, twenty-six members and nine visitors present.

The minutes of the 406th meeting were read and approved.

The Executive Committee reported the doings of its 172d and 173d meetings.

* At the adjourned meeting of the Board, held December 12th, the following applications were received and placed on file: George B. Christie, Ferd. E. Gaasche, George A. Lederle, and Jesse Lowe.

Applications for membership were announced from W. A. Layman, S. E. Johannessen and F. E. Bausch. The committee has adopted a rule that the library cards recently issued expire July 1, 1895, and that new cards, good until July 1, 1896, be issued by the Treasurer on payment of dues for 1895.

President Crosby read the following report of the Executive Committee, which was ordered filed:

To the Engineers' Club of St. Louis.

GENTLEMEN:—In accordance with the requirements of the constitution, I submit the following annual report of your Executive Committee for the year 1894:

Your committee has held twenty-four meetings. They have approved twelve applications for membership. Nine resignations have been received and accepted. Three members have been dropped for non-payment of dues, leaving the total membership of the Club unchanged.

Your committee has approved for payment fifty-one bills, amounting to ($1,290.29) twelve hundred and ninety and twenty-nine hundredths dollars, divided among the following accounts:

For the JOURNAL	$584 25
Rent	337 50
Miscellaneous expenses connected with rooms, including moving	89 03
Library	35 66
Printing and stationery	122 65
Postage	21 20
Salary of Secretary for 1893	100 00
Total	$1,290 29

Six of the papers read before the Club have been approved for publication in the JOURNAL.

In accordance with the vote of the Club, at the last meeting in December, 1893, your committee entered into an agreement, on behalf of the Club, with the Missouri Historical Society for the use of their meeting room, and for a separate room for the exclusive use of the Engineers' Club as a library and reading room, this agreement covering a period of two years from January 1, 1894.

The rooms of the Historical Society being open on week days from 9 A.M. to 6 P.M., make the library of the Club more accessible than it has been in the past, and, consequently, of more value to the members.

There have been a number of additions to the library during the past year, and the leading engineering periodicals of the United States have been kept on file.

The index to the library is very incomplete, and your committee would recommend that steps be taken to bring it up to date and make it as full and complete as possible. There are many valuable reports and books of reference in the library, and when the condition of the funds of the Club will allow, we think that it would be of benefit to the members of the Club to have an index of the library printed for distribution among the members.

At the beginning of the present year your committee made a careful estimate of probable expenditures for the year, and decided that they would be able to meet all expenses with the annual dues fixed at eight dollars ($8) for resident members and five dollars ($5) for non-resident members, being a reduction of two dollars for resident members from last year's assessment. The result has proved that these estimates were practically correct, and that the dues as fixed above, would have yielded a sufficient amount to cover all expenses if all the members had paid up, but, unfortunately, there are a number of delinquents, and the amount that is still uncollected will all be required to meet the balance of the expenses for the current year, the bills for which will be presented during this month.

Your committee feel that in the case of most of the delinquents, the non-payment is simply the result of forgetfulness on the part of the members, and realize that in some few instances it may be the result of the business depression of the past year, which has affected our profession as well as others, and deprived some of our members of steady employment. We trust, however, that all of those members

who possibly can do so, will at once remit their dues to the Treasurer, so that we can start clear on the new year without a deficit.

THE EXECUTIVE COMMITTEE,
B. L. CROSBY, *President.*

The Secretary then read the following report, which was ordered received and filed:

Members of Engineers' Club of St. Louis.

GENTLEMEN:—The work of the past year may be summarized as follows: There have been eighteen meetings—fifteen at 1600 Lucas Place, two at Washington University and one at the Mercantile Club, a gain of two meetings over last year. The total number of recorded meetings is now 406.

President Crosby occupied the chair at fourteen meetings, Vice-President Russell at two and Mr. Robert Moore at two.

The total attendance of members was 537; an average of thirty, a gain of four over the average of last year. The recorded number of visitors is 107 for fifteen meetings, an average of seven.

Eleven papers have been read and ten addresses of a more or less formal character have been delivered. The members contributing papers were Messrs. Kinealy, Dean, Laird, R. E. McMath, Robert Moore, Condron, Molitor, Stuart, Woermann, Herman and Wheeler.

Those who delivered addresses were Messrs. Robert Moore, Bartlett, Olshausen, J. B. Johnson, Holman, Russell, Eayrs, Laird, C. C. Brown and C. M. Woodward.

Thirteen gentlemen have been elected to membership, seven members have been dropped for delinquency and seven have resigned. Two members dropped have been reinstated. One gentleman who was elected decided not to qualify. These figures indicate that the Club has just held its own in membership. Closer scrutiny, however, shows that four of the members dropped for delinquency are properly chargeable to the year 1893, so that there has actually been a gain in membership of four. There are now upon our rolls one honorary member, 129 resident members and 49 non-resident members, a total of 179.

The Club is to be congratulated upon the increased interest evinced by the members, as shown in the larger number of meetings and the greater average attendance, both of members and of visitors, as well as in the high grade of papers and addresses and the discussions accompanying them.

Respectfully submitted,
W. H. BRYAN, *Secretary.*

The Secretary also read the following report for the Librarian, which was ordered received and filed:

To the President and Members of the Engineers' Club.

GENTLEMEN: Only recently elected Librarian, I have not yet had time to make myself thoroughly familiar with the condition of the library. I can say, however, that its status has not materially changed during the past year; only a few additions have been made to it, the most important being Prof. Johnson's book on "Framed Structures," Prof. Howe's "Steel," the *Engineering News* and *Railroad Gazette.* The above periodicals, as well as the *Transactions of the American Society of Civil Engineers* and Proceedings of the Associated Engineers Societies, are bound at the end of each year for future reference.

Owing to large general expenses during the last two years, the appropriation from the Club's funds for the library was only $93.10 in 1894. The Club's finances will probably permit greater liberality for this purpose in 1895. The Library Committee have fixed on $150 per year for the next five years as the sum desired for the library. This may be beyond the Club's means, and an effort is now being made to induce fifty (or more) members to guarantee any deficiency from this amount, not more than $3 to be called for from each subscriber.

A complete new index, rearrangement and general cleaning up of all books and periodicals, and a judicious weeding out of trade catalogues, circulars and miscellaneous papers, is urgently needed, and is recommended to my successor's attention at his very earliest convenience. Respectfully submitted.

E. A. HERMANN, *Lilrarian.*

The Secretary then read the following report for the Treasurer:

Statement of account of Executive Committee with Chas. W. Melcher and Thos. B. McMath.

DEBITS.

To balance as per report December 6, 1893	$49 19	
Receipts brought forward	203 00	
		$252 19

RECEIPTS ISSUED.

126 resident at $8.00	$1,008 00	
47 non-resident at $5.00	235 00	
14 initiations at $10.00	140 00	
Dues for new members, 1894	50 50	
Wahlert changed to resident	8 00	1,441 50
Dues for new members, 1893		9 00
Sales of "Local Data"	2 63	
Dues overpaid	2 00	4 63
Balance from 1893 supper		4 05
Total debits		$1,711 37

CREDITS.

By bills approved, 400 to 451	$1,272 28	
Receipts cancelled (Melcher)	69 00	
Receipts cancelled (McMath)	78 00	
		1,419 28

RECEIPTS ON HAND.

1893 receipts	30 00	
1894 resident members receipts	152 00	
1894 non-resident members receipts	25 00	
Cash balance on hand	85 09	292 09
		$1,711 37

LIBRARY FUND—DEBITS.

To balance entertainment fund	56 10	
To balance Chicago fund	35 00	
B. L. Crosby	2 00	
		93 10

CREDITS.

By bills 426, 427, 430, 433	35 66	
Cash balance on hand	57 44	
		$93 10
Total cash on hand	$142 53	

Respectfully submitted.

Thomas B. McMath, *Treasurer.*

Ordered that same be referred to the Executive Committee to be audited.

Col. E. D. Meier, chairman of the Committee on Monument to James B. Eads, reported verbally that for various good reasons but little had been accomplished during the past year. He had good reason to believe, however, that the additional funds necessary could be raised this winter, and that the monument would be built during the coming year. He requested that the committee be increased to five, the additional members to be appointed by the chair. So ordered.

On behalf of the Committee on Smoke Prevention, Mr. Bryan stated that owing to the continued absence from the city of Prof. Potter, chairman, no formal report had been prepared. It was hoped, however, that an entire evening would be given to this subject in the near future. Committee continued.

Mr. Laird, chairman of the Committee on Library, stated that the reports of the Executive Committee and Librarian covered the status of the library very fully; he added that the subscription list to the guarantee fund of $150 annually was growing in a quite satisfactory manner. Committee continued.

Prof. Johnson, one of the Club's representatives on the Board of Managers of the Association of Engineering Societies, and chairman of that body, read the following report, which was ordered received and filed :

To the Engineers' Club of St. Louis.

Gentlemen:—Your representatives on the Board of Managers of the Journal of the Association of Engineering Societies beg leave to report as follows:

About a year ago Mr. Benezette Williams having resigned from the Chairmanship of the Board, a position which he had filled with ability and credit from the organization of the association, your senior representative on the board was elected to the vacancy caused by Mr. Williams' resignation. At the same time Mr. John C. Trautwine, Jr., of Philadelphia, was elected secretary of the board, and the place of publication changed from Chicago to Philadelphia. Mr. Trautwine has shown great ability and devotion in discharging the duties of secretary, and we think the Journal has never before been so well edited and printed. The current volume of proceedings will be larger than any previous volume, and the illustrations have been more numerous and of a much higher order than heretofore.

The board has incurred during the past year a number of unusual expenses. The total cost of changing the secretary and the place of publication was not far from $500, and the greater amount of matter published has also added something to our annual expenses. There was, besides, a deficit in the accounts of the former administration of about $400, which the board has undertaken to discharge during the current year. The new secretary has succeeded, however, in increasing the income of the association from advertisements by several hundred dollars, which partly offsets these extra expenses.

It seemed desirable to the members of the board to make as good a showin in our publication this year as possible, hoping thereby to attract new subscribers, new advertisements and perhaps induce some of the other local societies to join the association. The general financial depression has, however, operated against us and we have not succeeded in increasing the subscriptions and advertisements as much as we had hoped. Three prominent local engineering societies are seriously contemplating joining the association, and others have it under advisement. On the other hand, the Western Society af Engineers, of Chicago, have proposed to withdraw from the association, and have, in fact, given notice to the board of withdrawal three months before the end of the fiscal year, in accordance with the articles of association. They have, however, submitted the question to a letter ballot, and the result of this ballot is to be declared this evening. It is probable that the vote will be nearly a tie on the subject of withdrawing. This action on their part has been prompted not by any cause of dissatisfaction with the management of the Journal, but from a desire to place their society upon a national and independent footing, and to raise it out of that class of so-called local societies. If they should decide to withdraw, it would reduce the number of paying subscribers to the Journal by about 250. It is probable, however, that this number will be fully made up within a few months by the combined membership of other local societies which will decide to join the association.

One great difficulty the board contends with in the matter of advertisements is that no one cares to interest himself sufficiently to procure such advertisements, as they probably would do if each society published its own proceedings. Furthermore, persons advertising in such journals usually do so through a sort of favoritism, and not purely as a matter of business, their object being to help along the enterprise. In our case, however, they always reply that since this journal is supported by a number of societies, we do not need that kind of assistance, and whereas the St. Louis advertiser would ge glad to assist the St. Louis Engineers' Club he has no interest in assisting the Boston Society for instance. These facts tend to explain the meager amount of advertising usually found in our journal.

As a result of the increased expenditures which the board has been obliged to

meet during the past year, a special assessment will probably be levied at the end of the year to cover any deficit which may remain. More especially will this be necessary if the Western Society decides to withdraw. So far as your members of the board are aware, no other society in the association is dissatisfied with the present state of affairs or contemplates withdrawing.

Respectfully submitted,
J. B. JOHNSON,
S. B. RUSSELL,
Members Board of Managers.

In the absence of Mr. Julius Pitzman, chairman of the Committee on Boulevards, Prof. Chaplin stated briefly the present status of that work. Committee continued.

In the absence of Mr. Flad, chairman of the Committee on Compensation of Engineers, Mr. Bryan stated that it had been impossible as yet to secure a full meeting of the committee, but that the chairman had mapped out a plan of operation which would undoubtedly accomplish something in the near future. Mr. Robert Moore stated that he considered the work of this committee foreign to the objects of the club, and beneath its dignity, and moved that the committee be discharged. This motion was seconded by Mr. Wheeler, and after discussion by Messrs. Bryan, Crosby, Kinealy, Laird, Sterne, Holman and Johnson, was carried.

The Committee on Nomination of officers for the coming year submitted the following report:

To the President and Members of the St. Louis Engineers' Club.

GENTLEMEN :—Your committee chosen to nominate a list of officers for the ensuing year beg leave to submit the following report :

For President—S. Bent Russell.
For Vice-President—J. A. Ockerson.
For Secretary—Wm. H. Bryan.
For Treasurer—Thos. B. McMath.
For Librarian—J. N. Judson.
For Directors—B. L. Crosby and Wm. Bouton.
For Members Board of Managers—J. B. Johnson and William E. Barns.

Respectfully submitted,
C. M. WOODWARD,
ROBERT MOORE,
J. B. JOHNSON.

Additional nominations being called for, Prof. J. H. Kinealy was nominated for Vice-President.

On motion it was ordered that the annual supper be held on the evening of December 19th, and that the Executive Committee make the necessary arrangements. Adjourned.

WILLIAM H. BRYAN, *Secretary.*

408TH MEETING, DECEMBER 19, 1894.—The annual supper was held at the Mercantile Club, beginning at 8.10 P.M.; the attendance being forty-four members and eight visitors, President Crosby in the chair.

After justice had been done to the supper, the report of the 176th meeting of the Executive Committee was read, announcing the resignations of F. E. Turneaure

A. L. Tuttle, C. W. Stewart and A. S. Cushman. The Executive Committee recommended a contribution, by the club, of $10 from the library fund towards the publication, in complete shape, of Ex-State Geologist Winslow's report on the lead and zinc deposits of the State; the contribution to be conditional upon the club receiving two copies of the report for its library. On vote, the club approved the recommendation.

The Executive Committee reported the result of the letter ballot for officers for 1895, as follows: President, S. Bent Russell; Vice-President, J. A. Ockerson; Secretary, William H. Bryan; Treasurer, Thomas B. McMath; Directors, B. L. Crosby and Wm. Bouton; Librarian, J. N. Judson; Members Board of Managers Association of Engineering Societies, J. B. Johnson and W. E. Barns.

Retiring President Crosby introduced Mr. Russell, the president-elect, who took the chair and called on Mr. Crosby for an address. The latter gentleman then read an address on the St. Louis extension of the St. Louis, Keokuk & Northwestern Railroad, describing fully the tracks, yards, bridges, culverts, paving, ballast, grades, curves and other features of interest. Particular attention was paid the Bellefontaine bridge across the Missouri River. After discussion by Messrs. Holman, Judson, Wheeler, Johnson and Kinealy, it was, on motion, voted that further discussion be postponed until a later meeting. Adjourned.

William H. Bryan, *Secretary.*

Montana Society of Civil Engineers.

December 8, 1894.—The regular monthly meeting of the Montana Society of Civil Engineers was held December 8, at 7.30 p.m., at the office of Messrs. Sizer & Keerl. There were present members, Messrs. Haven, Keerl, Herron, F. J. Smith, Wickes, Wheeler, Griffith, Relf, Cumming and Hovey, and one visitor. President Haven in the chair. Mr. H. C. Relf was appointed secretary of the meeting.

The minutes of the last meeting, having been printed in *The Independent,* and a copy sent to each member, were approved without being again read. Applications for admission as members from the following gentlemen were read, viz.: C. M. Thorpe, city engineer of Bozeman; F. W. Blackford, city engineer of Butte; Paul S. A. Bickel, county surveyor-elect, of Lewis and Clarke County, Helena; A. A. Morris, county surveyor-elect of Yellowstone County, Billings; C. A. Dewar, civil engineer, Billings; and James Breen, metallurgist, mining engineer, Butte.

Ballots were taken and the following gentlemen were declared unanimously elected as members of the Society: Eugene Carroll, chief engineer and superintendent of the Butte City water works, Butte; James Henry Henley, director of the American Developing and Mining Company, Helena; Malcolm M. Macdonald, United States deputy mineral surveyor, Butte; Walter W. Pennington, surveyor, Butte; Robert A. McArthur, engineer of mines, Butte.

By consent of the meeting, the order of proceedings was changed and the President made an explanation of the circumstances under which, during the last two months, he has attended to the duties of the Secretary, Mr. Foss being absent in Arizona, and no acting secretary having been appointed. The meeting approved of the President's action.

A letter from James McFarlane, member of the Montana Society of Engineers, was read, suggesting that the Society discuss and take action upon some practical matters, such as the free and unlimited coinage of silver; also a letter from Roy

Stone, special agent of the road inquiry section of the Department of Agriculture, Washington, D. C., offering his aid in any efforts of our Society in the matter of good roads, and stating that nearly all the state legislatures would take up the subject this winter.

The President stated that Prof. A. M. Ryon, having been in New York for three weeks, was unable to present to the meeting his corrected and printed report on the water movement. As soon as it is received it will be sent to the members, and it will come up for final action at the annual meeting.

Mr. W. A. Haven then read three proposed amendments to the by-laws, and explained why it would be desirable to adopt them. It was voted that they be printed and sent to the members for ballot, to be counted at the annual meeting.

The committee on annual meeting reported progress. The committee on county surveyor and road laws not being ready to report, their chairman, Mr. E. R. McNeill, sent a letter and a draft of the amendments to the present statutes of Montana, which were partially agreed upon by them. This communication was read by the Secretary, and the subject was discussed in a lively manner for an hour by all the members present, and it was then voted "that when the full report of the committee is received by the President, he is authorized to have 150 copies of it printed, and a copy sent to each member, with a request that they submit, in writing, as early as practicable, their opinions, and such suggestions and alterations as may seem to them advisable, and that the suggestions be transmitted without delay to the committee, who are instructed to prepare a revised bill for presentation to the legislature, after final action thereon by the Society at the annual meeting."

The meeting adjourned at 10.15 P.M.

H. C. Relf, *Secretary pro tem.*

Report of Committee on County Surveyors and Road Laws.

Helena, Montana, Dec. 22, 1894.—Your Committee on "County Surveyors and Road Laws," appointed November 10, 1894, with instructions to investigate and report to the Society such amendments to the statutes of Montana as seem to them advisable for the purpose of defining more exactly the compensation and duties of County Surveyors, and also to insure more efficiency and economy in the matter of the expenditure of the money of the people in the matter of the laying out, construction and repairs of highways and highway bridges, than is obtainable by the present method, or want of method, in these things by the present statutes, report as follows: That the time was too short to enable them to obtain full data, from all the counties, about the present expensive way of the expenditure of the road tax, but from data obtained in the counties in which they reside, it is apparent to them that over one hundred thousand dollars ($100,000) is *annually* expended for "repairs of roads" in Montana, without any apparent result in the improvement of the roads. We find by our correspondence with the County Commissioners throughout the State, who are without exception able bodies of men, that they all desire that the supervision of highways and highway bridges—the laying out, construction and repairs—should be placed in the hands of some officer, responsible to them, who shall be competent by education and experience to know exactly what is necessary to be done, and who is able to estimate the cost thereof, in all new work, and the repairs of all old roads and bridges. The present "road laws" seem to have been made up from various statutes of some of the Eastern States, where the counties were small in area, and it was supposed that all of the Com-

missioners were personally acquainted with all parts of the county, and these statutes are not at all adapted to Montana, where all the conditions are entirely different, and it is physically impossible for the Commissioners to know anything about the wants of a district distant from the county seat, but in these cases they are dependent upon reports made by the road supervisors, few of whom have any technical knowledge or experience in making good roads or keeping them in repair. It therefore seems to your committee that the time has arrived when our State of Montana should adopt some better system, more in touch with the modern way now prevailing in all the other States of the Union. Your committee has received and read dozens of recent publications from Roy Stone, Esq., the "Special Agent and Engineer in Charge of the Road Inquiry of the U. S. Department of Agriculture," Washington, D. C., giving data as to laws recently passed or introduced in the legislatures of other States; but taking into consideration the peculiar conditions of Montana, its mountains and plains, we submit the following as our idea of what legislative enactments Montana should adopt to begin a system of economy and efficiency in these matters. We first give a copy of the statutes relating to "County Surveyors," and then our suggestions as to amendments thereto. The various "Road Laws" are in a printed pamphlet, and we have merely made such alterations in them as were necessary to make them conform to the amendments proposed in the County Surveyors' laws and the new duties required of them.

Thomas T. Baker,
Fred. P. Gutelius,
E. R. McNeill,
Committee.

County Surveyor.

[Copied from the Compiled Statutes, page 882.]

Section 898. A county surveyor shall be elected for the term of two years, who shall give bond to the board of county commissioners, to be approved by the county clerk, of the proper county, in the sum of one thousand dollars, conditioned by the faithful discharge of his duties.

Sec. 899. The county surveyor may appoint as many assistants as he may think proper, for whose official acts he shall be responsible. The certificate of the county surveyor, or any of his deputies, shall be admitted as legal evidence in any court of the territory, but the same may be explained or rebutted by other evidence.

Sec. 900. It shall be the duty of the county surveyor, by himself or one of his deputies, to execute any survey which may be required by any court, upon the application of any individual or corporation, and shall execute any survey required by the board of county commissioners. He shall be paid for his services seven dollars per day, while making the survey, the amount, in the first instance, to be paid by the person or corporation for whose benefit the survey is made, and in the other, by the county commissioners, by order on the county treasurer, against the proper fund.

Note.—Section 900 of March 12, 1885.

Sec. 901. The said surveyor shall keep a correct and fair record of all surveys made by him or his deputies in a book to be provided for that purpose by the county, which shall be transmitted to his successor in office. He shall also number each survey progressively, and shall preserve a copy of field notes and calculations of each survey, endorsing thereon its proper number, a copy of which, and also

a fair and accurate plat, together with a certificate of survey, shall be furnished by said surveyor to any person requiring the same.

SEC. 902. If the office of county surveyor be at any time vacant, the board of county commissioners are hereby empowered to appoint some suitable person to perform the duties of the office until a county surveyor be elected.

COUNTY SURVEYOR AND SUPERVISOR OF ROADS.

[Proposed amendments to Sec. 898 to 902, inclusive (Compiled Statutes).]

SEC. 898. An officer having the title of County Surveyor and Supervisor of Roads, and who shall be a competent engineer and surveyor, shall be elected for a term of two (2) years, who shall give bond to the board of county commissioners, to be approved by the county clerk of the proper county, in the sum of from one (1) to five (5) thousand dollars, conditioned on the faithful discharge of his duties.

SEC. 899. The county surveyor and supervisor of roads may appoint one or more assistants, as may be deemed necessary by the county surveyor, supervisor of roads and county commissioners, for whose official acts he shall be held responsible, The certificate of the county surveyor and supervisor of roads, or any of his deputies, shall be admitted as legal evidence in any court of the State, but the same may be explained or rebutted by other evidence.

NEW SECTION. The county surveyor and supervisor of roads shall be supervisor of all public highways and highway bridges as to repairs, improvements and construction of new highways and bridges in the several districts of the county, all such work to be under his supervision or one of his deputies ; he shall be ex-officio chairman of all boards of road viewers, and shall, with the assistance of the other members of said board, make an accurate survey of the road as laid out by the said board, making proper connection with some natural object, permanent monument or corner of the public survey, and make an estimate of the cost of new roads or bridges, repairs or improvements, and a plat or plan of such survey and estimate to be submitted to the board of commissioners as a part of the report of the viewers.

ANNUAL REPORT. It shall be the duty of the county surveyor and supervisor of roads to prepare and submit to the board of commissioners at their August meeting, a full and complete report of all road expenditures for the year past, and to report on the condition of the roads in the several districts under his charge, with such recommendations and estimates of cost for maintenance and improvements during the ensuing year as, in his judgment, seems expedient—the report to designate specifically the different portions of road to be improved, the nature of improvements and an estimate of the amount of material of different classes required.

The county surveyor and supervisor of roads shall furnish plans and specifications for all contracts to keep roads and bridges in repair, or to build new roads and bridges, and it shall be his duty to direct the contractor in carrying out the work, according to said plans and specifications, and he shall be held responsible for the proper fulfillment of the same.

Proposed substitute for amended Section 900 :

It shall be the duty of the county surveyor and supervisor of roads, by himself or one of his deputies, to execute any survey which may be required by any court, upon the application of any individual or corporation, and he shall be paid for his services ten dollars per day and expenses, while engaged in making the survey and plat, and shall be paid for the same by the individual or corporation making the application.

The said county surveyor and supervisor of roads shall receive as compensation for his services to the county:

In all third class counties	$1,500.00 per annum
In all second class counties	1,800.00 per annum
In all first class counties	2,000.00 per annum

and all necessary travelling expenses to be authorized by the county commissioners. In consideration of the compensation received from the county, the said county surveyor and supervisor of roads shall execute all surveys and make all plats required by the county commissioners that shall be for the general good of the county.

Sec. 901. The said surveyor and supervisor of roads shall keep a correct and plain record of all surveys made by him or his deputies, in a book provided for that purpose by the county, which shall be transmitted to his successor in office. He shall also number each survey progressively, and shall preserve a copy of the field notes and calculations of each survey, endorsing thereon its proper number, a copy of which, and also a plain and accurate plat, together with a certificate of survey, shall be furnished by said surveyor and supervisor of roads to any person requiring the same.

Sec. 902. If the office of county surveyor and supervisor of roads be at any time vacant, the board of county commissioners are hereby empowered to appoint some competent person to perform the duties of the office until a county surveyor and supervisor of roads be elected.

And be it further enacted, That in case the freeholders of any road district, representing two-thirds of the assessed valuation of all the property in said district shall decide to levy a special road tax in their district, it shall be the duty of the county clerk, upon a receipt of a petition signed by freeholders representing two-thirds of the assessed valuation of the road district, stating therein the amount of such levy, to make such levy against all the assessed property in said road district, and it shall be the duty of the county treasurer to collect the same and set it aside for road improvement only within the road district in which the special tax was voted.

Civil Engineers' Club of Cleveland.

December 11, 1894.—The meeting was called to order at the rooms of The Electric Club of Cleveland, at 7.55 p.m., by the President. Forty-seven members and visitors were present. The minutes of the meeting of November 13th were read and approved. The report of the Executive Board was read and approved. The President appointed Messrs. W. P. Brown and D. C. Miller tellers for the evening.

Mr. Wason, in behalf of the Committee on Quarters, made a very complete report, giving the names and rentals for rooms in various buildings. He also read a proposition from the Electric Club of Cleveland in regard to using its rooms for the present. Mr. Culley moved that the report of the Committee on Quarters be accepted. Seconded by Mr. Bowler and passed. Mr. Culley moved the acceptance of the proposition of the Electric Club of Cleveland. The motion was seconded by Mr. Roberts and discussed by Messrs. Roberts, Wason, Herman, Howe, Benjamin, Searles, Culley, Porter and Swasey. A vote was then taken and the motion passed. Mr. Searles moved that a vote of thanks be extended to The Electric Club of Cleveland for its kindness and hospitality to us in our time of need, and that its

members be assured of our appreciation and of our hope of reciprocating the favor at some time. The motion was seconded and passed.

The tellers announced, through the Secretary, the election to active membership of Mr. Harry S. Nelson.

Mr. Searles made inquiry as to the belongings of the Club at Case Library, as to whether we could find a place for them in the rooms of the Electric Club. Mr. Austin said that he thought no trouble would be found in finding a place for them.

The paper of the evening was then read by Prof. Morely on "The Mechanical Action of Magnetism on Light." The subject was discussed by Col. Smith and Prof. Morley.

The meeting adjourned at 9.50 P.M.

A. LINCOLN HYDE, *Secretary pro tem.*

Boston Society of Civil Engineers.

DECEMBER 19, 1894.—A regular meeting of the Boston Society of Civil Engineers was held at its rooms, 36 Bromfield Street, Boston, at 7.50 o'clock P.M., President William E. McClintock in the chair. Ninety-eight members and visitors present.

The record of the last meeting was read and approved.

Messrs. Alonzo K. Crowell, Abram S. N. Estes, Allen Hazen, John C. Moses, Macy S. Pope and Daniel L. Turner were elected members of the Society.

The Secretary read a memoir of Charles W. S. Seymour, prepared by a committee of the Society, consisting of M. M. Tidd, F. M. Hersey and C. W. Howland.

The President, for the Board of Government and the Committee on Headquarters, reported progress in the matter of securing more commodious quarters for the Society's library.

Mr. James W. Rollins, Jr., Resident Engineer of the N. Y., N. H. & H. R. R., at Brockton, opened the evening's discussion by reading a very interesting paper, entitled "Abolition of Grade Crossings, particularly those on the Providence Division and at Brockton on the Old Colony Railroad."

Mr. Charles A. Allen spoke on the general subject of the abolition of grade-crossings, and gave a history of what had been done at Northampton, Mass. Mr. John W. Ellis spoke briefly on the subject, and Mr. F. Herbert Snow discussed the question from the municipal side. Messrs. G. A. Kimball and E. K. Turner also took part in the discussion.

On motion of Mr. Manley, the thanks of the Society were voted to Mr. Rollins for his able paper.

Adjourned.

S. E. TINKHAM, *Secretary.*

CHARLES W. S. SEYMOUR.

A Memoir.

By M. M. TIDD, F. M. HERSEY AND C. W. HOWLAND, COMMITTEE OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read December 19, 1894.]

Charles W. S. Seymour was born in Hingham, Mass., September 1, 1839. He received his education in the public schools of that town.

After following various pursuits, his father, who was a local surveyor, having on account of failing health become unable to continue his work, the son Charles, who had been his assistant for several years and learned the use of instruments and the necessary details of surveying, making plans, calculating areas, etc., took up the practice of surveying and became well-known throughout Plymouth County as an uncommonly reliable surveyor.

In 1879, The Hingham Water Company was organized, and the work of construction was commenced under the direction of M. M. Tidd, of Boston, a member of this Society, who employed Mr. Seymour as his principal assistant, and found him a man of superior mechanical ability, being possessed of remarkable versatility, fertile in expedient and quick of comprehension. In the construction of these works he obtained the experience which made him a most competent superintendent and general manager of those works, from June, 1880, when the water was first turned into the pipes, until the day of his death.

The business of the company with which he was thus connected increased rapidly, and the pipe system was extended to Nantasket Beach and Hull; these extensions being made under Mr. Seymour's direction.

As a man and a citizen Mr. Seymour was held in high esteem by all who knew him, and the many public positions of trust and responsibility to which he was elected by the voters of his native town and county testify to their appreciation of his worth.

He became a member of the Boston Society of Civil Engineers October 17, 1888, and continued his membership during his life.

The cares of his many duties as Superintendent of the Water Works, and his strict attention and close application to business resulted in his death by apoplexy, October 15, 1893.

As a friend and associate no more intelligent, genial, agreeable and thoroughly companionable man has ever been connected with our Society than Charles W. S. Seymour.

INDEX TO CURRENT LITERATURE.

In this department is given an Index of current periodical engineering literature. To each title is appended a short note indicating the character of the article indexed. The index notes are printed on but one side of the paper, so that the titles may be cut out and pasted upon cards or in a book. At the end of the yearly volume the Index is reprinted in full, with additions and cross-references.

All readers of the JOURNAL are requested to aid in making this Index as complete as possible. Notices for this department, and all matter to be indexed, should be sent to J. B. JOHNSON, Manager of Index Department, Washington University, St. Louis, Mo.

LIST OF PERIODICALS INDEXED.

Following the title of each periodical is given, in italics, the abbreviation by which it is referred to in the Index.

For alphabetical list of abbreviated titles, see page iv.

UNITED STATES.

ANNUAL.

American Institute of Mining Engineers, Transactions of the — (*Trans. A. I. M. E.*), 13 Burling Slip, New York; per year, $5.

American Society of Mechanical Engineers, Transactions of the — (*Trans. A. S. M. E.*), 12 West Thirty-first Street, New York.

Society of Naval Architects and Marine Engineers, Transactions of the—(*Trans. N. A. & M. E.*), W. L. Capps, Secretary, 1710 F Street N. W., Washington, D. C.: $10 per annual volume.

QUARTERLY.

Engineers' Club of Philadelphia, Proceedings of the — (*Proc. Eng. Club Phila.*), 1122 Girard Street, Philadelphia, Pa.; per year, $2.

New England Water Work Association, Journal of the — (*Jour. N. E. W. W. Assn.*), New London, Conn.; per year, $2; single copies, 75 cents.

School of Mines Quarterly (*Sch. Mines Quart.*), Columbia College, New York City; per year $2; single copy, 50 cents.

Technology Quarterly and Proceedings of the Society of Arts (*Tech. Quart.*), Massachusetts Institute of Technology, Boston, Mass.; per year, $3.

United States Naval Institute, Proceedings of the —(*Proc. U. S. N. I.*), United States Naval Institute, Annapolis, Md.; per year, $3.50; single copy, $1.

MONTHLY.

SOCIETIES.

American Institute of Electrical Engineers, Transactions of the — (*Trans. A I. E. E.*), 12 West Thirty-first Street, New York City.

American Society of Civil Engineers, Transactions of the — (*Trans. A. S. C. E.*), 127 East Twenty-third Street, New York; per year, $10.

Association of Engineering Societies, Journal of the — (*Jour. Assn. Eng. Socs.*), Philadelphia; per year, $3; single copy, 30 cents.

Engineers' Society of Western Pennsylvania, Proceedings of— (*Proc. Eng. Soc. W. Pa.*), Allegheny, Pa; per year, $7; single copy, 75 cents.

Franklin Institute, Journal of the — (*Jour. Frank. Inst.*), Franklin Institute, Philadelphia Pa.; per year, $5; single copy, 50 cents.

Technical Society of the Pacific Coast, Transactions of the — (*Trans. Tech. Soc. Pac. C.*), Rooms 56–57, 819 Market Street, San Francisco, Cal.

MONTHLY—Continued.

PERIODICALS.

American Engineer and Railroad Journal (*Am. Eng. & R. R. Jour.*), 47 Cedar Street, New York; per year, $3; single copy, 25 cents.

Cassier's Magazine (*Cassier*), World Building, New York; per year, $3; single copy, 25 cents.

Engineering Magazine (*Eng. Mag.*), 47 Times Building, New York; per year, $3; single copy, 25 cents.

Engineering Mechanics (*Eng. Mech.*), 430 Walnut Street, Philadelphia, Pa.; per year, $1; single copy, 10 cents.

Inland Architect and News Record (*Inland Arch.*), The Inland Publishing Co., 19 Tribune Building, Chicago; per year, $5; single copy, 50 cents; Photogravure Edition, per year, $10; single copy, $1.

Irrigation Age (*Irrigation Age*), Chicago, Ill.; per year, $2.

Master Steam Fitter (*Mst. Stm. Fitter*), 218 La Salle Street, Chicago, Ill.; per year, $1; single copy, 10 cents.

Paving and Municipal Engineering (*Pav. & Munic. Eng.*), Municipal Engineering Co., 44 Chamber of Commerce, Indianapolis, Ind.; per year, $2; single copy, 25 cents.

Power (*Power*), World Building, New York; per year, $1; single copy, 10 cents.

Railway Engineering and Mechanics (*Ry. E. & M.*), 816 The Rookery, Chicago, Ill.; per year, $1; single copy, 10 cents.

Safety Valve (*Sy. Valve*), 55 Liberty Street, New York; per year, $1; single copy, 10 cents.

Street Railway Journal (*St. Ry. Jour.*), World Building, New York; per year, $4; single copy, 35 cents.

Stone (*Stone*), Chicago; per year, $2; single copy, 25 cents.

Street Railway Review (*St. Ry. Rev.*), 269 Dearborn Street, Chicago, Ill.; per year, $2; single copy, 25 cents.

WEEKLY.

American Architect (*Am. Arch.*), Ticknor & Co.; 211 Tremont Street, Boston, Mass.; single copy, 15 cents.

American Machinist (*Am. Mach.*), 96 Fulton Street, New York; per year, $2; single copy, 10 cents.

Boston Journal of Commerce (*Bos. Jour. Com.*), 128 Purchase Street, Boston, Mass.; per year, $3; single copy, 6 cents.

Electrical Engineer (*Elec. Engr.*), 203 Broadway, New York; per year, $3.

Electrical World (*Elec. World*), 177 Times Building, New York; per year, $3; single copy, 10 cents.

Engineering and Mining Journal (*E. & M. Journal*), 27 Park Place, New York; per year, $5; single copy, 15 cents.

Engineering News (*Eng. News*), Tribune Building, New York; per year, $5; single copy, 15 cents.

Engineering Record (*Eng. Rec.*), 277 Pearl Street, New York; per year, $5; single copy, 12 cents.

Railroad Gazette (*R. R. Gaz.*), 73 Broadway, New York; per year, $4.20; single copy, 10 cents.

Scientific American Supplement (*Sci. Am. Sup.*), 361 Broadway, New York; per year, $5; single copy, 10 cents.

Street Railway Gazette (*St. Ry. Gaz.*), Monadnock Block, Chicago; per year, $3; single copy, 25 cents.

CANADA.

Canadian Society of Civil Engineers, Transactions of the — (*Trans. Can. Soc. C. E.*), McGill University, Montreal.

GREAT BRITAIN.

Electrical Review (*Elec. Rev.*), 22 Paternoster Row, London, E. C.; weekly; per year, 21s, 8d; single copy, 4d.

Engineer, The — (*Lon. Engineer*), London, England; weekly; per year, $10; single copy, 25 cents.

Engineering (*Lon. Eng.*), London, England; weekly; per year, $10; single copy, 25 cents.

Engineering Review (*Eng. Rev.*), 29 Great George Street, S. W., England; monthly; single copy, 6d.

Institution of Civil Engineers, Proceedings of the — (*Proc. Inst. C. E.*), 25 Great George Street, Westminster, S. W., London, England.

Institution of Mechanical Engineers, Proceedings of the — (*Proc. Inst. Mech. Engs.*), 19 Victoria Street, Westminster, S. W., London, England.

WEEKLY.—Concluded.

Mechanical World (*Mech. World*), Manchester, England; weekly; per year, 8s, 8d.

Practical Engineer (*Prac. Engr.*), 2 Amen Corner, London, E. C., England; weekly; per year 10s.

Railway Engineer (*Ry. Eng.*), 8 Catherine Street, Strand, W. C., London, England; monthly. single copy, 1s.

INDIA.

Indian Engineer (*Ind. Engr.*), Calcutta, India; per year, 20 Rs.

Indian Engineering (*Ind. Engng.*), Calcutta, India, weekly; per year, 18s; single copy, 8 annas.

FRANCE.

Ponts et Chaussées, Annales des — (*Annales des P. & C.*), monthly, Vve. Ch. Dunod, 49 Quai des Augustins, Paris, France.

Société des Ingénieurs Civils, Mémoires de la — (*Méms. Soc. Ing. Civils*), monthly, 10 Cité Rougement, Paris.

GERMANY, AUSTRIA AND SWITZERLAND.

Archiv für Eisenbahnwesen (*Arch. f. Eisenbw.*), bi-monthly, Julius Springer, Berlin, Germany; per year, 12 marks.

Civilingenieur, Der — (*Civ. Ing.*), monthly.

Deutsche Bauzeitung (*Deutsche Bztg.*), semi-weekly, Berlin, Germany; per year, 12 marks.

Journal für Gasbeleuchtung und Wasserversorgung (*Jour. f. Gasb. u. Wasserv.*), three times a month, 11 Glückstrasse, Munich, Germany; per year, 20 marks.

Praktische Maschinen-Constructeur, Der—(*Pr. Msch. Cnstr.*), bi-weekly, Leipzig-Gohlis, Germany; per year, 16 marks.

Schweizerische Bauzeitung (*Schw. Bztg.*), German and French, 32 Brandschenkestrasse, Zurich.

Zeitschrift des Oesterreichischen Ingenieur und Architekten Vereins (*Ztsch. Oest.*), weekly.

Zeitschrift des Vereines Deutscher Ingenieure (*Ztsch. Ver. Ing.*), weekly, Berlin, Germany; per year, 32 marks.

For alphabetical list of abbreviated titles, see page vii.

Alphabetical List of Abbreviated Titles

OF PERIODICALS INDEXED.

For list of full titles, see page i.

Am Arch. *American Architect*, Boston; weekly.
Am Eng & R R Jour. *American Engineer & Railroad Journal*, New York; monthly.
Am Mach. *American Machinist*, New York; weekly.
Annales des P & C. *Annales des Ponts et Chaussées*, Paris, France; monthly.
Arch f Eisenbw. *Archiv für Eisenbahnwesen*, Berlin, Germany; bi-monthly.
Bos. Jour. Com. *Boston Journal of Commerce*, Boston, Mass.; weekly.
Cassier. *Cassier's Magazine*, New York; monthly.
Civ Ing. *Der Civilingenieur;* monthly.
Deutsche Bztg. *Deutsche Bauzeitung*, Berlin, Germany; semi-weekly.
E & M Journal. *Engineering and Mining Journal*, New York; weekly.
Elec Eng. *The Electrical Engineer*, New York; weekly.
Elec Rev. *Electrical Review*, London, Eng.; weekly.
Elec World. *The Electrical World*, New York; weekly.
Eng Mag. *The Engineering Magazine*, New York; monthly.
Eng Mech. *Engineering Mechanics*, Philadelphia, Pa.; monthly.
Eng News. *Engineering News*, New York; weekly.
Eng Rec. *Engineering Record*, New York; weekly.
Eng Rev. *Engineering Review*, London, Eng.; monthly.
Ind Engng. *Indian Engineering*, Calcutta, India; weekly.
Ind. Engr. *Indian Engineer*, Calcutta, India; weekly.
Inland Arch. *The Inland Architect and News Record*, Chicago, Ill.; monthly.
Irrigation Age. *The Irrigation Age*, Chicago, Ill.; monthly.
Jour Assn Eng Socs. *Journal of the Association of Engineering Societies*, Philadelphia; monthly.
Jour f Gasb u Wasserv. *Journal für Gasbeleuchtung und Wasserversorgung*, Munich, Germany; three times a month.
Jour Frank Inst. *Journal of the Franklin Institute*, Philadelphia, Pa.; monthly.
Jour N E W W Assn. *Journal of the New England Water Work Association*, New London, Conn.; quarterly.
Lon Eng. *Engineering*, London, England; weekly.
Lon Engineer. *The Engineer*, London, England; weekly.
Mst. Stm. Fitter. *Master Steam Fitter*, Chicago, Ill.; monthly.
Mech World. *The Mechanical World*, Manchester, England; weekly.
Mems Soc Ing Civ. *Mémoires de la Société des Ingénieurs Civils*, Paris; monthly.
Pav & Munic Eng. *Paving and Municipal Engineering*, Indianapolis, Ind.; monthly.
Power. *Power*, New York; monthly.
Pr Msch Cnstr. *Der Praktische Maschinen-Constructeur*, Leipsic.
Prac. Engr. *Practical Engineer*, London; weekly.
Proc Eng Club Phila. *Proceedings of the Engineers' Club of Philadelphia*, Philadelphia, Pa.; quarterly.
Proc Eng Soc W Pa. *Proceedings of Engineers' Society of Western Pennsylvania*, Pittsburg, Pa.; monthly.
Proc Inst C E. *Proceedings of the Institution of Civil Engineers*, London, England
Proc Inst Mech Engrs. *Proceedings of the Institution of Mechanical Engineers*, London, England
Proc U S N I. *Proceedings of the United States Naval Institute*, Annapolis, Md.; quarterly.
R R Gaz. *Railroad Gazette*, New York; weekly.
Ry E & M. *Railway Engineering and Mechanics*, Chicago, Ill.; monthly.
Ry Eng. *The Railway Engineer*, London, England; monthly.
Sch Mines Quart. *School of Mines Quarterly*, New York City.
Schw Bztg. *Schweizerische Bauzeitung*, Zurich; German and French; weekly.
Sci Am Sup. *Scientific American Supplement*, New York; weekly,
Stone. *Stone*, Chicago, Ill.; monthly.
St Ry Gaz. *The Street Railway Gazette*, Chicago, Ill.; weekly
St Ry Jour. *Street Railway Journal*, New York; monthly.
St Ry Rev. *Street Railway Review*, Chicago, Ill.; monthly.
Sy Valve. *Safety Valve*, New York; monthly.
Tech Quart. *Technology Quarterly and Proceedings of the Society of Arts*, Boston, Mass
Trans A I E E. *Transactions of the American Institute of Electrical Engineers*, New York City.
Trans A I M E. *Transactions of the American Institute of Mining Engineers*, New York.
Trans A S C E. *Transactions of the American Society of Civil Engineers*, New York; monthly.
Trans A S M E. *Transactions of the American Society of Mechanical Engineers*, New York
Trans Can Soc C E. *Transactions of the Canadian Society of Civil Engineers*, Montreal.
Trans N A & M E. *Transactions of the Society of Naval Architects and Marine Engineers*, Washington, D. C.; annual.
Trans Tech Soc Pac C. *Transactions of the Technical Society of the Pacific Coast*, San Francisco, Cal.
Ztsch Oest. *Zeitschrift des Oesterreichischen Ingenieur und Architekten Vereins;* weekly.
Ztsch Ver Ing. *Zeitschrift des Vereins Deutscher Ingenieure*, Berlin, Germany; weekly.

For list of full titles, see page i.

INDEX.

ANNUAL SUMMARY.

For lists of periodicals indexed, see pages i and iv.

Aberration. *Constant of* ——. See *Coast and Geodetic Survey.*

Abrasives. *Emery and Other* ——. A lecture by T. Dunkin Paret before the Franklin Institute. *Jour. Frank. Inst.*, May, 1894, *et seq.*

Accounts *for Street Railways.* Report of Committee of American Street Railway Association on a standard form of street railway accounts. *St. Ry. Jour.*, Nov., 1894.

Accumulators. *Copper Zinc* ——. A paper by Dr. Paul Schoop. *Elec. Eng.*, Jan. 24, 1894.

————. *in Central Station Railway Work in Switzerland, St. Ry. Rev.*, July, 1894.

Acoustics. *The Measurement of Sound Intensities.* A number of interesting experiments to show that although the vis viva of sound varies as the square of the distance, the effect of its intensity on the human ear varies directly as the distance. Also an application of these principles to the acoustic properties of interiors. Mr. A. Sturmhoefel in *Deutsche Bztg.*, Jan. 13, 1894, pp. 24–27.

Aerial Navigation. See *Navigation, Aerial* ——.

Aerodynamics. An analysis of the functions of a bird's wing during flight and its mechanical imitation, by S. D. Mott, M. Am. Inst. Elec. Engrs. *Sci. Am. Sup.*, Aug. 11, 1894.

Aeronaut. *Engineering Materials for the* ——. A discussion of the relative weights and strengths of different materials. *Prac. Engr.*, Sept. 28, 1894.

Aeronautics. *Experiments in* ——. Popular article, giving an historical account mainly of personal work with the supporting device and motive power of a flying machine. Hiram S. Maxim. *Sci. Am. Sup.*, Dec. 29, 1894, *et seq.*

————. *Materials in* ——. Relative values of different metals, woods, etc., considered by Prof. R. H. Thurston. *Cassier*, Sept., 1894.

———— See *Aerodynamics.*

Agricultural Implements *at the Agricultural Fair at Berlin, 1894.* Article by Grimdke, describing various new German agricultural implements—of small value, however to Americans. *Ztsch. Ver. Ing.*, Nov. 3, 1894.

Air. *Compound* —— *Compressor.* Illustrated description of a compound air compressor, built by the South Norwalk Iron Works. *Am. Eng. & R. R. Jour.*, Feb., 1894, p. 76.

————. *Compressed* ——. Relative cost of compressed air and steam under different conditions. *Am. Mach.*, Nov. 22, 1894.

————. *Compressed* ——. *Uses of* —— *in a Repair Shop.* By F. M. Twombly, Master Mechanic New York, New Haven and Hartford R. R. *Ry. E. & M.*, Nov., 1894.

————. *The Upper* ——. Methods of systematic explorations, with estimates of cost, considered by Mark W. Harrington, Chief of Weather Bureau. *Aer.*, Sept., 1894.

————. *Transmission of Power by* ——. A paper by A. E. Chodzko, discussing compound air compressors. *Am. Eng. & R. R. Jour.*, Aug., 1894.

————. See *Shaft Sinking.*

Air Brakes. See *Railroads, Brakes.*

Air *Compressors.* See *Power, Compressors.*

Air-Lift Pump. See *Pump.*

Aluminum. *Its Alloys and their Use in the Arts.* By M. A. Spiral. *Mems. Soc. Ing. Civ.*, April, 1894, pp. 507–542.

Aluminum.—Continued.

————. *Processes Employed in the Extraction and Refining of Metals by Electrolysis, with Especial Reference to Aluminum.* By Ch. Haubtmann. An illustrated article describing the important processes of obtaining the metal from its ore. *Méms. Soc. Ing. Civ.*, April, 1891, pp. 396-506.

————. *Properties of* ——. A paper by A. Humboldt Sexton, giving some of the properties of the various alloys of aluminum. *Prac. Eng.*, Oct. 12, 1894.

————. *The Manufacture of* ——. Abstract of paper read by W. S. Sample before the Manchester Association of Engineers. *Am. Eng. & R. R. Jour.*, June, 1894.

————. *The Properties and Uses of* ——. Abstract of the report of Alfred E. Hunt, M.A. Soc. C. E., and President of the Pittsburg Reduction Co., made for the Government Report on the Mineral Resources of the United States for 1892. Presents much new and valuable information concerning this metal. *Eng. News*, Feb. 8, 1894.

————. *The Superabundant Metal.* Historical account of the discovery and manufacture of the metal, with a forecast of its future, by Henry Wurtz. *Eng. Mag.*, Dec., 1894.

Aluminum Bronze. Its manufacture, properties and usefulness where strength and durability are desired. By Dr. Leonard Waldo. *Eng. News*, Oct. 11, 1894.

Alloys. *Researches on the Properties of* ——. By Prof. W. C. Roberts-Austen. Second Report to the Alloys Research Committee of the British Institute of Mechanical Engineers. *E. & M. Journal*, Jan. 20, 1894.

Analysis. *The Chemical —— of Public Water Supplies.* See *Water Supplies.*

Animal Power. See *Power.*

Aqueduct. *Canal* ——. Built of steel girders resting on masonry piers. Length of span, 131 feet. Total length, 2,174 feet. Situated at Briare, France, on the River Loire. *Lon. Eng.*, Nov. 30, 1894.

Arbitration and Conciliation. *Plans to Facilitate Arbitration and Conciliation between Employers and Employees.* By M. A. Gibon. A long article from the point of view of an employer. *Méms. Soc. Ing. Civ.*, May, 1891, p. 791.

Arch Bridge. *Stony Creek* ——. See *Bridge.*

Arches. An article on the theory of ——, accompanied by a diagram giving depths of keystone for different spans according to different formulas. *Eng. News*, March 15, 1894.

———— *Concrete and Iron* —— on the Melan system which employs bent I-beams embedded in concrete without tie-rods. An instructive article, well illustrated. *R. R. Gaz.*, April 13, 1894.

————. *Masonry Arch Bridges in Galicia on the Stanislau-Woronienka Railway.* Illustrated description and a few details of seven large arch railway bridges recently constructed in Galicia over the Pruth River; spans, 72 to 213 feet. *Eng. News*, Dec. 7, 1893, pp. 477-8. *Ztsch. Oest.*, Oct. 20, 1893.

————. *Parabolic* ——. Discussion, with equations for maximum stresses and moments. By J. Al. Belliard. *Annales des P. & C.*, July, 1894.

————. *Theory of Masonry* ——. Based on the principle of least resistance. By Prof. W. H. Burr. *Selected Papers of the Rensselaer Society of Engineers* of Troy, N. Y. Jan., 1894.

Architectural *Education.* Report of the Committee on Education to the American Institute of Architects, suggesting ways of improvement and lines of progress. *Inland Arch.*, Nov., 1894.

Architecture. *American —— as Seen Through English Spectacles.* Article of popular import. By Banister Fletcher, A. R. I. B. A. *Eng. Mag.*, June, 1894, Vol. VII, pp. 314-321.

———— *and High Buildings.* Thomas Hastings considers that the height of buildings in cities should be limited, not only for practical and sanitary reasons, but also for the sake of architectural effect. *Am. Arch.*, Nov. 17, 1894.

———— *as a Profession.* A popular article by R. W. Gibson. *Eng. Mag.*, Dec., 1893, Vol. VI, pp. 323-329.

————. *Colonial* ——. G. C. Gardner writes of and illustrates this subject as exemplified in Western Massachusetts. *Am. Arch.*, Sept. 15, 1894.

————. *Gothic* ——. Its rise, teachings and principles, and ending. Conrad Bryant Schaefer. *Inland Arch.*, Dec., 1894.

———— *in Philadelphia.* Recent buildings described and [extensively illustrated. By Prof. W. P. Laird. *Eng. Mag.*, Oct., 1894.

Association. *Convention of American Railway Master Mechanics* ——. Abstract of proceedings of meeting of June, 1894. *Am. Eng. & R. R. Jour.*, July, 1894.

Astronomical *Observations for Latitude.* See *Surveying, Geodetic* ——.

Asylums. *Modern* —— *for the Insane.* A series of articles. *Am. Arch. & Building News*, Nov. and Dec., 1893.

Atalantis *and How It Will Be Built.* Proposed plans for the foundations for a hotel in the open ocean. *Eng. News*, Jan. 28, 1894.

Atmospheric *Resistance.* Paper by Prof. Walter L. Webb giving results of tests to determine the —— to the free fall of spheres. *Proc. Eng. Club, Phila.*, Nov., 1894.

Axles. *Comparative Advantages of Collared and Collarless* ——. *Eng. News*, June 28, 1894.

————. *Strength of Car* ——. Results of investigations and observations of fractures to determine proportions. *R. R. Gaz.*, Dec. 21, 1894.

Balancing *of Reciprocating Parts of Machinery.* By W. Worby Beaumont. Reprint from *Journal of the Society of Arts. Sci. Am. Sup.*, April 7, 1894.

Ball Bearings. "*A New Mechanical Fluid.*" Condensed from a paper read before the American Society of Mechanical Engineers at Montreal, describing novel uses of balls in bearings to take the place of fluids. *Eng. News*, June 7, 1894. *Iron Age*, June 14, 1894.

————. See *Steel Tapes.*

Balloons. *Hydrogen Gas* ——. The process of manufacture described by Carl E. Myers. *Aer.*, Sept., 1894.

Base-Lines. *On the Measurement of the* —— *at Holton, Ind., and St. Albans, W. Va.* Methods and results in the use of the iced bar and metallic tape measurements. *U. S. C. & G. Survey, Appendix No. 8*, Report for 1892.

Base Line Apparatus. A description of base line apparatus and method of use. *Annual Report upon River Improvement in the South*, in charge of J. H. Williard, being *Appendix V of Annual Report of the Chief Engineers* for 1893.

Base Line Measuring. *Long Tape* —— *Apparatus.* Describing appliances and methods used in Mississippi River surveys. By H. M. Marshall, U. S. Asst. Eng. *Eng. News*, July 12, 1894.

———— *with Steel and Brass Tapes.* See *Surveys of Red River.*

Batteries, *some Phenomena of Storage* ——. W. W. Griscom shows that the current of a cell constantly fluctuates, with differing results, and gives methods for increasing the steadiness. *Trans. A. I. E. E.*, June and July, 1894.

————, *Storage* ——. A description of the street-cars and batteries in use on the line or the Second Avenue Railway Co., of New York, since June 1, 1893. A profile of the road is given. Also the operating expenses of the cars. *St. Ry. Jour.*, Dec., 1893.

————. *Storage* ——. Description of the Tudor battery used in the Central Station of the Edison Electric Illuminating Co., Boston. *Elec. Eng.*, April 4, 1894.

————. *Storage* ——. Qualities necessary and recent improvements made, with especial description of the Payen cell. *E. & M. Jour.*, Dec. 22, 1894.

————. *Storage* ——. Tests of ——. By Robert McA. Lloyd. Suggests a form of report. *Elec. Eng.*, April 25, 1894, pp. 366-7.

————. *Storage* ——. Their discovery and perfection, with probable and possible future uses, by Pedro G. Salom. *Cassier*, Dec., 1894.

————. *Storage* —— *for Central Stations.* Appendix to report submitted at the twelfth annual meeting of the American Street Railway Association. Gives additional data as to cost and running expenses. *St. Ry. Jour.*, Dec., 1893, p. 833. *Elec. Eng.*, Dec. 20, 1893, p. 527.

Battleship. *The* —— *as a Fighting Machine.* General description of the ship, its machinery, armament and armor, by George W. Melville, Engineer-in-Chief, U. S. N. *Eng. Mag.*, Aug., 1894.

————. *Turret and Turret-Moving Machinery of the United States* —— "*Texas.*" An illustrated article describing the turret engines, reversing valves, air compressor, etc. *Am. Eng. & R. R. Jour.*, April, 1894.

Beams. *Proportioning Wooden* ——. Diagrams for the purpose, with the theoretical discussion of their deviation, by Carl S. Fogh. *Eng. News*, Sept. 27, 1894.

Boiler.—Continued.

————. *Erwin Herz's New* ——. Paper by Herz read before the Austrian Society of Engineers and Architects. The paper is illustrated and contains several new ideas; the practical value of which, however, seems doubtful. *Ztsch. Ver. Ing.*, Nov. 3, 1894.

———— *Explosions.* Article by R. H. S. Thurston, giving table showing the total stored energy in different types of boilers. *Prac. Engr.*, Nov. 9, 1894.

————. *External Corrosion of Steam* ——. Illustrated article showing several examples of external corrosion. *Mech. World*, June 22, 1894.

————. *Fusible Plugs for* ——. Short article giving melting points of alloys of various compositions used for fusible plugs. *Power*, Sept., 1894.

————. *Horse-Power of Common Tubular* ——. From three tests made, the results of which are given in full, Mr. Jay M. Whitham concludes that the best economic results are obtained when the boiler is so operated as to give one horse-power for every nine square feet of water-heating surface. *Power*, Dec., 1893, p. 8.

————. *Horse-power and Steam Space of* ——. An article giving tables and diagrams showing steam space and horse-power of different makes of boilers. *Power*, Sept., 1894.

————. *How to Operate a Steam* ——. An extremely good paper by Jarvis B. Edson, M.E., describing the proper care and firing of boilers. *Elec. Eng.*, March 21, 1894.

————. *Locomotive* ——. Cones formed on baffle plates by action of draft. Photograph of ——. *R. R. Gaz.*, Jan. 26, 1894.

————. *Making Tests of a* ——. Paper by Chas. Day, describing method of procedure and apparatus to be used. *Prac. Eng.*, Sept. 21, 1894, *et seq.*

————. *Mechanical Stokers.* The Jones Underfeed. Description and drawings. Operated by a ram driven by steam which pushes the fuel into a retort provided with tuyeres. *R. R. Gaz.*, Jan. 26, 1894.

———— *of the U. S. Battleship "Texas."* An illustrated description of the boilers and feed pump. *Am. Eng. & R. R. Jour.*, May, 1894.

————. *Steel for* ——. Report of Committee on Specifications for Boiler Steel of American Railway Master Mechanics' Association. *Am. Eng. & R. R. Jour.*, July, 1894.

————. *Strong's Internally Fired Return Tubular* ——. Description of the plant at the Ridgewood Pumping Station, Brooklyn. *Eng. News*, Aug. 23, 1894. *Iron Age*, Aug. 23, 1894. *R. R. Gaz.*, Aug. 23, 1894. *Eng. Rec.*, Aug. 25, 1894. *Power*, Sept. 1894. *Ind. Eng.*, Nov. 17, 1894.

————. *Test of* ——. Evaporative test of a Cornish boiler fitted with heat-conducting web plates, by M. Longbridge. *Prac. Engr.*, Nov. 16, 1894.

————. *Test of* ——. Results of four tests made by Geo. H. Barrus, on a Stirling boiler at the power house of the Portland (Me.) Railroad Co. *Power*, May, 1894.

————. *Tests of Steam Boilers.* Paper read by O. Knaudt before the Society of Engineers of the Lower Ruhr concerning tests at the Electric Exhibition at Frankfort. Short and illustrated, discussing results of tests. *Ztsch. Ver. Ing.*, Sept. 15, 1894.

————. *The Belpaire Locomotive* ——. Illustrated description in detail of boiler used on Lehigh Valley Railroad. *Am. Eng. & R. R. Jour.*, Aug., 1894.

————. *The Corrosion of the* ——. The appearance, causes and means of avoiding the blisters causing the corrosion. By M. Olny, Engineer-in-Chief of Mines. *Annales des P. & C.*, July, 1894.

————. *The Hazelton or Porcupine* ——. A decription of this boiler and some tests made on it. Given in a paper read by Dr. A. W. Wilkinson before the Society of Gas Lighting. *Power*, Jan., 1894.

————. *The Testing of a* ——. See *Engines.*

————. *The Yarrow* ——. A description of the Yarrow boiler. *Am. Eng. & R. R. Jour.* June, 1894.

————. *Water-tube* ——. Discussion before the American Society of Mechanical Engineers at its monthly meeting on May 9th. *Am. Mach.*, May 17, 1894, *et seq.*

Boilers. *Chilling Action of Feed-water on* ——. Description of experiments to determine the chilling action of feed-water on boilers. *Power*, Nov., 1894.

————. *Construction and Inspection of* ——. A paper read before the November meeting of the New York Railway Club. *R. R. Gaz.*, Dec. 22, 29, 1893.

Brake. *Air —— and Brake-rigging.* Article with diagrams by James Howard. Read before Central Railway Club. *Ry. Rev.*, Dec. 30, 1893.

————. *Air —— for Street Cars.* An illustrated description of the improved Genett air brake. *St. Ry. Jour.*, May, 1894.

————. *A New Form of the Prony ——*, in which an elliptical copper tube with hydraulic pressure is used. By Prof. R. C. Carpenter. Illustrated. *Eng. News*, Dec. 7, 1893. *Cassier*, Feb., 1894.

————. *Power Brakes.* E. J. Wessels points out the necessity of brakes more powerful than the hand brakes, and claims superiority of air brakes over electric brakes. *R. R. Gaz.*, Oct. 19, 1894. *St. Ry. Gaz.*, Oct. 20, 1894. *Eng. News*, Oct. 18, 1894. *St. Ry. Rev.*, Oct , 1894; *St. Ry. Jour.*, Nov. 1894.

————. *The Electric ——.* Its great practical advantages advocated in an illustrated article by Elmer A. Sperry. *Trans. A. I. E. E.*, Aug. and Sept., 1894. *St. Ry. Gaz.*, Sept. 29, 1894, *et seq.*

————. *Leverages of ——.* A diagram of the lever gear of freight cars. *Ry. E. & M.*, Feb., 1894, p. 31.

Brakes. *Air ——.* Rack tests at Altoona by M. C. B. Committee, including the Westinghouse, New York, Boyden, Crane and Lansberg brakes. For full data address John W. Cloud, Secretary M. C. B. Association, Chicago. Abstract in *Eng. News*, Feb. 1, 1894. *Ry. Rev.*, Feb. 3, 1894.

————. *Efficiency of Air and Foundation ——.* Instructive article. Diagrams showing loss of pressure between air-brake cylinder and brake beam, as determined by standing tests. *Eng. News*, May 3, 1894. *Ry. E. & M.*, May, 1894.

————. *High Speed and Quick Action ——.* Brief demonstration of their advantage. Illustrated by curves. *R. R. Gaz.*, May 25, 1894.

————. See *Railroads.*

Brake Shoes. D. F. Henry and Powell Evans advocate uniformity in brake shoes for street cars, and suggest essential features. *St. Ry. Rev.*, Oct., 1894. *R. R. Gaz.*, Oct. 19, 1894. *St. Ry. Gaz.*, Oct. 20, 1894. *Eng. News*, Oct. 18, 1894. *St. Ry. Jour.*, Nov., 1894.

————. *Foreign Practice in ——.* Illustrations. *R. R. Gaz.*, May 18, 1894.

————. *Test of ——.* Illustrated article describing the machine devised by the M. C. B. Committee for laboratory tests of brake shoes. *Ry. E. & M.*, Nov., 1894.

Brakeshoe Tests *by the Master Car Builders' Association.* With description and cut of the testing machine. *Eng. News*, June 28, 1894.

Breakwater *at Copenhagen, Denmark.* An illustrated description showing concrete construction, etc. *Eng. Rec.*, March 31, 1894. *Eng. News*, July 26, 1894.

————. *at Port Crescent, Washington.* Description of a loose-rock dike, by A. S. Going, A.M., Can. Soc. C. E. *Trans. Can. Soc. C. E.*, Oct.-Dec., 1893.

Brick. *Manufacture of ——.* A well illustrated article of a general descriptive character by C. H. Schuman, C. E. *Cassier*, Oct., 1893.

————. *Paving ——.* Methods of manufacture and composition and properties of proper clays. W. S. Ravenscroft. *Pav. & Munic. Eng.*, Dec., 1894.

————. *Paving ——. Tests of ——.* See *Tests.*

————. *Paving and Building ——.* Methods and results of 100 tests by E. S. Fickes, with editorial comments. *Eng. News*, Dec. 13, 1894.

————. *The Manufacture and Use of ——.* Abstract from a paper by D. W. Mead, C. E. Read before the International Engineering Congress at Chicago. *Pav. & Munic. Eng.*, Jan., 1894.

————. *Transverse Strength of —— Masonry.* Experiments on —— made by M. A. Earl and A. B. Loomis, of the University of Illinois. Abstracted from *The Technograph. Eng. News*, Dec. 28, 1893.

————. See *Pavements, Paving, Tests.*

————. *A 182-feet Span Plate Girder Swing ——.* Illustrated. *Eng. News*, July 26, 1894.

————. *Paving ——. Tests of ——.* See *Tests.*

Bridge. *An Automatically Acting Lift ——.* Described by M. Roussel, as erected to replace a drawbridge. *Annales des P. & C.*, July, 1894.

————. *Anchorage of Trestle Bent of Minneapolis Western Railway —— over Mississippi River.* By Olaf Hoff. Illustrated. *Eng. Rec.*, Dec. 16, 1893, pp. 37-38.

Bridge.—Continued.

————. *Renewal of Bridges on J. T. & K. W. Ry.* Illustrated and described by C. R. Knight. *R. R. Gaz.*, July 6, 1894.

————. *Renewal of Filbert Street Bridge, Philadelphia, Pa., without Interruption of Traffic.* Six tracks. Brief illustrated description. *R. R. Gaz.*, May 18, 1894.

————. *Salado, Argentine Republic.* 126 feet 6 inches, riveted spans, metal floor. *Eng. Rec.*, Jan. 27, 1894.

————. *Specifications.* See *Bridge Loads.*

————. *Stony Creek Arch, Canadian Pacific Railway.* Description and general details of this 336-feet steel arch. *Eng. News*, Aug. 2, 1894.

————. *Strains in Hinged Suspension* ——. By Prof. M. A. Howe. *Jour. Assn. Eng. Socs.*, Dec., 1893.

————. *"Structural Motion" in* ——. Georgia bridge of the Central Vermont Railroad. An article showing that statics alone should not be an aboslute criterion of design. By Geo. H. Thomson. *Ry. Rev.*, June 2, 1894.

————. *Structural Motion of* ——. The Stockport ——, designed by Geo. H. Thompson, for the N. Y. C. and H. R. R. R. Details of bridge and article on the structural motion caused by moving loads. *R. R. Gaz.*, Dec. 22, 1893.

————. *Suspension* ——. Extended and careful discussion of stresses, deformation and effects of loads upon the floor system and cables of suspension bridges, by M. T. Godard. *Annales des P. & C.*, Aug., 1894.

————. *Test of* —— *to Destruction.* Procedure and results of a valuable test of an iron railway bridge on the Jura-Simplon Railway. *Annales des P. & C.*, June, 1894. *R. R. Gaz.*, July 13, 1894.

————. *The Brooklyn* ——. Details of construction and operation of the Brooklyn bridge. Lecture by G. Leverich. *The Polytechnic*, Nov., 1894. *R. R. Gaz.*, Nov. 23, 1894.

————. *The Brooklyn* ——. Illustrated paper giving details of the proposed New York terminal station designed to double the efficiency of the bridge railway. *Eng. News*, Nov. 8, 1894. *St. Ry. Gaz.*, Nov. 10, 1894.

————. *The Brooklyn* —— *at Cleveland, Ohio.* Description, with drawings in detail of this new bridge. *Eng. News*, Oct. 25, 1894.

————. *The Burlington* ——. Its original construction in 1867–8, by C. H. Hudson. *Jour. Assn. Eng. Socs.*, May, 1894.

————. *The Lyon Brook Bridge and Viaduct of the N. Y. O. & W. R. R. near Norwich, N. Y.* Illustrated description. By Albert Lucius. *R. R. Gaz.*, March 2, 1894.

————. *The North River* ——. Report of expert engineers to the Secretary of War, on "Safe and practicable length of span." *Eng. Rec.*, Sept. 8, 1894. *R. R. Gaz.*, Sept. 7, 1894. *Eng. News*, Sept. 6, 1894. *Eng. News*, Nov. 22, 1894, *et seq.*

————. *The North River* ——. Appendix to the report of the Engineer Commission, containing the plans and estimates of the Union Bridge Company, for cantilever bridge of 2,160 feet span. *Eng. Rec.*, Oct. 13, 1894. Appendix containing the theory of the continuous stiffening truss. *Eng. Rec.*, Oct. 20, 1894. Appendix containing a discussion by W. Hildebrand of the feasibility of a suspension bridge 3,200 feet span. *Eng. Rec.*, Oct. 27, 1894. Appendix containing modified plan and estimate by W. Hildebrand. *Eng. Rec.*, Nov. 3, 1894. Appendix giving memorial of the commercial interests of New York. *Eng. Rec.*, Nov. 3, 1894. Appendix giving design of proposed bridge to Hoboken by G. Lindenthal. *Eng. Rec.*, Nov. 10, 1894.

————. *The Railway* —— *in Canada.* Marcus Smith, M. Inst. C. E., treats of the use of iron and coal in construction. *Proc. Inst. C. E.*, Vol. 117.

————. *The Results of the Budapest* —— *Competition.* Illustrated. *Eng. News*, June 28, 1894.

Bridges. A comparison of Cooper's, Launhardt's and Weyrauch's formulas. By Prof. Edgar Marburg. *Eng. News*, June 14, 1894.

————. *The Winona Highway* ——. Complete description, with illustrations. *Eng. Rec.* Aug. 25, 1894.

————. *Tower* ——, *London.* Full description, with numerous illustrations. *The Engineer*, Dec. 15, 1893. *Eng. News*, Jan. 18, 1894. *Eng. Rec.*, Dec. 30, 1893. *Eng. Rev.*, July, 1894. *Sci. Am. Sup.*, Aug. 25, 1894.

Bridges.—Continued.

————. *Foundations of* ——. Renewal of a pier of the Cincinnati & Muskingum Railway Bridge over the Scioto River. By Morton L. Byers. Illustrated. *Trans. A. S. C. E.*, March, 1894.

————. *Foundation of Cheat River* ——. Illustrated description. *Eng. News*, April 12, 1894.

————. *Howe Truss* ——, *Construction and Maintenance of* ——. Interesting paper. By Chas. H. Nichols, C.E. *Proc. Eng. Soc. W. Pa.*, 1893, pp. 53-74.

————. *Interstate Bridge at Omaha, Neb.* Article with inset sheet and details of draw machinery. By J. A. L. Waddell, M. Am. Soc. C. E., Chief Engineer. *Eng. News*, Dec. 7, 1893. Details of steel trusses, turning machinery and end-locking apparatus of the 520-foot swing span. Abstract from specifications for material. *Eng. News*, Dec. 7, 1893.

————. *Lift* —— *at Halsted Street, Chicago, Ill.* Illustrated description. *Eng. News*, April 19, 1894.

————. *Passaic* ——. Article with plans of discontinuous draw span for the New York, Lake Erie and Western Railroad. *R. R. Gaz.*, Dec. 1, 1893.

————. *Pin Plates of Bridge Trusses.* A very instructive account of tests of compression members. Failure occurred at the pin-holes. By Thos. H. Johnson, C.E. *Proc. Eng. Soc. W. Pa.*, 1893, pp. 95-106.

————. *Pivot Pier of* ——. The removal of a defective pivot pier of a 290 feet draw span of the Arkansas and Texas Railway, crossing the Ouatchita River at Camden, Ark. By Howard G. Kelley. *Trans. A. S. C. E.*, March, 1894.

————. *Tests made with Balcke's Tension Meter for Bridges, Results of* ——. Gives a comparison of observed and computed tensions under stationary and moving loads for three bridges. *Deutsche Btzg.*, March 17, 1894.

————. *Wheel Loads for Bridges.* Paper by Theodore Cooper, C. E., proposing one standard of locomotive wheel loads, all other wheel loads to be derived from this one by simple percentages. Discussion of compromise train loads. *Trans. A. S. C. E.*, Feb., 1894.

Bridge Building and Repairs. Copious extracts from instructions issued by the Chief Engineer of the Chicago, Milwaukee and St. Paul Railroad, for the employees of the bridge and building departments; embracing: duties of employees, bridge inspection, work sheets, renewals and repairs of bridges and culverts, iron bridges, danger signals, etc., care of boilers, office standards. *Eng. Rec.*, Jan. 13, 1894.

Bridge Deflections. *Frankel's Recording Extensometer for Measuring* ——. Requires no independent support, heavy weight being sunk to bottom of stream beneath the member to be observed. *Eng. News*, Feb. 8, 1894. *Ind. Engr.*, Dec. 16 and 23, 1893, Jan. 6, 1894.

Bridge Designing. *Notes on the Designing of Metallic Structures.* By O. J. Marstrand, in *The Polytechnic*, containing general office rules and instructions. *Eng. Rec.*, Feb. 17, 1894.

Bridge Eye Bars. *Forging of* —— *and the Flow of Metal in Closed Dies.* Concluding article by H. V. Loss, M.E., M. Am. Soc. C. E., describing motors and machines. *R. R. Gaz.*, Dec. 1, 1893, Jan. 19, 1894.

Bridge Failures. *Louisville and Jeffersonville Bridge. Erection and Fall of* ——. Articles accompanied by inset drawings; letters from prominent engineers. *Eng. News*, Dec. 28, 1893, Feb, 15, 1894. *Eng. Rec.*, Dec. 23, 1893, Jan 13, 1894. *R. R. Gaz.*, Dec. 29, 1893, Jan. 19, 1894. *Ry. Rev.*, Jan. 6, 1894. Letter from George H. Pegram, criticising the Pettit Truss, and making valuable suggestions for future practice. *R. R. Gaz.*, Jan. 26, 1894.

Bridge Loads. *Train Loads for Railroad Bridges.* Extracts from a paper before the American Society of Civil Engineers, January 3, by Theodore Cooper, M. Am. Soc. C. E., proposing a typical minimum train load to be increased by percentages for heavier traffic. Also tabulations of heavy car weights and loadings in actual use and classification of freight handled during twelve months by leading railroads. *R. R. Gaz.*, Jan. 12, 1894.

Bridge Piers. *Pivot Pier of Omaha Bridge, Omaha, Neb.* Full description of this pier, its caisson, etc. Illustrated. *Eng. Rec.*, March 3, 1894.

Briquette Fuel. *The Manufacture of* ——. Methods of procedure in the agglomeration of small coal into blocks suitable for use as fuel, by William Colquhoun. *Proc. Inst. C. E.*, Vol. 118.

Building. *American Tract Society's* ——. Extensive account of the foundation, steel frame and general features of this new New York structure, also general editorial. *Eng. News*, Dec. 27, 1894. *R. R. Gaz.*, Dec. 14, 1894. *Eng. Rec.*, Dec. 15, 1894.

Cast Iron. *Comparative Physical Tests of* ——. A paper by Thos. D. West, discussing the methods to be used in order to obtain comparative physical tests. *Am. Mach.* Aug. 30, 1894.

————. *Keep's Tests for* ——, given in pamphlet form, and fully illustrated. A complete system of practical tests of cast iron, to be used by the foundryman himself, to guide him in his mixtures. A very valuable addition to the literature of the subject. Address W. J. Keep, M. Am. Soc. M. E., Detroit, Mich. See also *Am. Mach.*, April 12, 1894, pp. 9-12.

————. *Testing Malleable* —— for tension, compression, bending and torsion, by Andrew George Ashcroft, Assoc. M. Inst. C. E. *Proc. Inst. C. E.*, Vol. 117.

————. *Tests on* —— in both tension and compression, made at Mass. Inst. Tech. Full records of over 100 tests, giving moduli of elasticity. *Tech. Quart.*, Vol. VII, July, 1894.

————. *The Strength and Resilience of* ——. Abstract of discussion read by Prof. J. B. Johnson before the Foundrymen's Association. *E. & M. Journal*, Aug. 25, 1894.

————. See *Foundry Mixtures, Pulleys.*

Cast Welding *Rail Joints.* Molten cast iron poured into moulds about the joint forms good weld with the steel rail ends. Cost \$3 per joint on Baden Railway at St. Louis. Illustrated description. *St. Ry. Rev.*, Dec., 1894.

Cement *and* —— *Testing.* A rather popular but very instructive article. By Spencer B. Newberry. *Eng. Mag.*, June, 1894.

———— *and Motar Tests* on natural and Portland cements, of ages from seven days to one year. A very complete series of tests, with tables and diagrams, made in the building of the Sault Ste. Marie Canal Lock. *Rep. Chf. Engrs. U. S. A.*, 1893, Vol. IV, p. 3009.

————. *Comparative Tests of* —— *by Flexure and Tension.* Continuation of tests made by F. J. Morrison and Herman Haupt for thesis work. First prize of *Eng. News* competition. *Eng. News*, May 10, 1894.

————. *Comparative Tests to Determine the Practicability of Testing Cement by Flexure.* A thesis by Mr. H. E. Abbott and Mr. E. J. Morrison, of the Thayer School of Civil Engineering, Dartmouth College, giving the results of many carefully made tests to determine the possibility of using this method in place of the customary method by tension. Prisms and briquettes made from the same mixture of cement, and comparisons and deductions made from their transverse and tensile strengths. Method thought to be reliable and much simpler, cheaper and quicker than the usual method. Details of an ingenious apparatus for testing. *Eng. News*, Dec. 14, 1893.

————. *Effect of Frost on Green Masonry* ——. The results of experiments by the Austrian Society of Architects and Engineers. Portland cement mortar mixed with salt recommended for laying brick or rubble masonry in freezing weather. *Eng. Rec.*, March 10, 1894. *Eng. News*, March 26, 1894.

————. *Experiments on Slag* ——. A paper by R. W. Mahon, giving in full the chemical analysis of slags used in making cements, and tests of these cements. *Jour. Frank. Inst.*, March, 1894.

————. *Hot-Bath Tests for* ——. Interesting paper showing that thoroughly hydrated lime present is no disadvantage to cement; that if sulphate of lime is added to defective cement, making it slow-setting, the hot test will not show defects; that the hot bath does not detect free lime. Extended discussion, with differing opinions, but mainly opposed to test. Frederick H. Lewis and J. Edward Whitfield. *Trans. A. S. C. E.*, Oct., 1894.

————. *Mortar.* Its cost for different proportions of sand, compared with strength, to determine maximum strength for a given cost, or minimum cost for a given strength. Diagrams shown. Comparison made in connection with the building of the Sault Ste. Marie Canal Lock. *Rep. Chf. Engrs. U. S. A.*, 1893, Vol. IV.

———— *Mortars in Freezing Weather.* M. J. Butler and others indicate methods and instances of successful use. *Trans. Can. Soc. C. E.*, Jan.-June, 1894.

————. *On the Manufacture and Testing of Portland* ——. A paper by Henry Faija, M. Inst. C. E. Prepared for the Engineering Congress at Chicago. *Trans. A. S. C. E.*, Oct., 1893, Vol. XXX.

————. *Testing of Portland* —— *and Development of the Cement Industry in Germany.* By Max Gary, C.E., Berlin. A valuable and well illustrated paper. Prepared for the Engineering Congress at Chicago. *Trans. A. S. C. E.*, Oct., 1893.

————. *Tests of Hydraulic Materials.* A paper bearing on chemical, physical and mechanical tests of cement. By H. Le Chatelier, Professor Ecole des Mines, Paris, France. *Trans. A. I. E. E.*, 1893.

Cement.—Continued.

————. *The Dry Method of Making Portland* ——. Historical résumé, and account of methods used by Chr. Engelhart, C.E. *Lon. Eng.*, June 1, 1894, *et seq.*

————. *Uniformity in Results of Testing Hydraulic* ——. Different results obtained by small differences in method. By Clifford Richardson. *Eng. Rec.*, Aug. 4, 1894.

Centrifugal Machines. *The Operation of* ——. Interesting discussion relating to the theory of these machines, the effect of centrifugal force, of counterbalancing, etc. By Prof. Gustav Hermann, of Germany. *Trans. A. S. M. E.*, 1893, Vol. XIV.

Centrifugal Pumps. See *Pumps.*

Chains. *Method of Manufacturing Weldless.* ——. An illustrated article describing the process of manufacturing weldless chains. *Amer. Eng. & R. R. Jour.*, Jan., 1894.

Channel. *The Chicago Drainage* —— *and Waterway.* A popular illustrated description. By G. P. Brown. *Eng. Mag.*, Aug., 1894.

Check Valve *for Stand-pipes.* See *Stand-pipes.*

Chili. *Mining, Metallurgy and Industries of* ——. By M. Ch. Vattier. *Mêms. Soc. Ing. Civ.*, July, 1892.

Chimney. *An Improperly Designed* ——. By Gustav Kaufman, C.E. *Proc. Eng. Soc. W. Pa.* 1893.

————. *Razing a* —— *by Means of Dynamite.* Short description of ——. *Eng. News*, May 17, 1894.

———— *Straigthening a Leaning* ——. Chimney one hundred feet high made vertical by excavation and the pull of cables. Joseph C. Platt. *Eng. News*, Dec. 13, 1894. *Trans. A. S. M. E.*, 1894.

Chimneys. *Expansion of Fire Bricks in* ——. Correspondence. *Eng. Rec.*, May 19, 1894.

————. *Steel* ——. *Design of* ——. Data respecting —— and formula for determining area of —— *Eng. News*, March 3, 1894. *Eng. Rec.*, March 3, 1894.

————. *Steel* —— *for Tall Office Buildings.* Description of chimneys for New York Life Insurance Building, Chicago, with detail drawings. *Eng. Rec.*, Feb. 3, 1894.

————. *The Large* —— *of the Edison Lighting Station of New York City.* Designed to avoid the bad effect of difference of expansion between the fire brick and the iron shell. Illustrated. *Eng. Rec.*, June 16, 1894.

————. See *Draft.*

Chronometer. *The Solution for the Elements of the* ——. Lieut. U. R. Harris gives the mathematical discussion, with tables and diagrams illustrating the rate curve for temperature. *Proc. U. S. N. I.*, Vol. XX, No. 2.

Circuit. *Importance of Complete Metallic* —— *for Electrical Railways.* Abstract of paper by J. H. Vail, read before the National Electric Light Association. *Elec. Eng.*, March 7, 1894, p. 199.

Circular Saw. *Power absorbed by a 56-inch* ——. Thesis of R. C. H. Heck and Henry B. Evans. Third prize of the *Engineering News* competition. A well illustrated and very interesting paper. *Eng. News*, March 15, 1894.

Cities. *Laying out of* ——. See *Surveying, City Engineer's Office.*

————. *Practical and Æsthetic Principles for the Laying out of* ——. General discussion by J. Stübben, Cologne, Germany. *Eng. Rec.*, Aug. 8, 1894, *et seq.*

City Engineer's Office. General methods of ——. By William E. McClintock. Discussion. *Jour. Assn. Eng. Socs.*, Oct., 1894.

———— *of Haverhill, Mass.* Organization of the office and general work of the departments. By J. T. Desmond. *Jour. Assn. Eng. Socs.*, Oct., 1894.

———— *of Providence, R. I.* Its departments and their organization ; details of work. By Otis F. Clapp. Discussion. *Jour. Assn. Eng. Socs.*, Oct., 1894.

————. *Organization and Composition of* —— *in Different American Cities.* By Albert F. Noyes. *Jour. Assn. Eng. Socs.*, Oct., 1894.

————. *Organization and Management of* ——. Discussion by Boston Society of Civil Engineers. *Jour. Assn. Eng. Socs.*, Oct., 1894.

————. *Public Parks in their Relation to* ——. By John C. Olmstead. *Jour. Assn. Eng. Socs.*, Oct., 1894.

Electricity.—Continued.

———— *Direct from Coal.* The great electro-chemical problem of the future scientifically discussed by Dr. William Ostwald, of the University of Leipsic. *Eng. Mag.*, Aug., 1894.

————. *Energy of* ——. See *Energy.*

————. *English Experience of Train Lighting by* ——. Axle lighting feasible for "block" trains. *R. R. Gaz.*, July 6, 1894.

———— *Generated by Windmills.* See *Windmills.*

———— *in 1876 and in 1893.* A popular historical article by Elihu Thomson. *Eng. Mag.*, Jan., 1894.

————. *Incandescent versus Arc Lighting.* The superiority of the incandescent light under ordinary methods of arranging the lights, with suggested method of utilizing maximum intensity of arc light. *Cassier*, October, 1894.

———— *in Mines.* Paper by W. E. Lishman, discussing the advantages of electricity over compressed air. *Prac. Engr.*, Sept. 21, 1894. *E. & M. Jour.*, Sept. 29, 1894.

———— *in Mines.* See *Mines.*

———— *in Mining.* See *Mining.*

———— *in the Modern City.* Abstract of lecture by Thomas Commerford Martin on the present and future uses of electricity. *Jour. Frank. Inst.*, Sept., 1894. *Jour. Frank. Inst.* Oct., 1894. Abstract in *R. R. Gaz.*, Oct. 12, 1894.

————. *Measurement of Self-induction and Investigation of the Phenomena of Alternating Currents of* ——. An apparatus for ——. By Frank A. Laws. Well illustrated. *Tech. Quart.*, Dec., 1893, Vol. VI.

————. *Meters of Electric Energy.* By M. P. G. Roux. *Mém. Soc. Ing. Civ.*, April, 1892.

————. *Methods of Charging for* ——. Comparatively considered by Alfred H. Gibbings, A. I. E. E. *Elec. Rev.*, July 27, Aug. 3 and 10, 1894.

———— *on Ships.* Abstract of paper read by S. D. Greene before the Society of Naval Architects and Marine Engineers, November 5th, at New York. *Elec. Eng.*, Nov. 21, 1894. *Eng. News.*, Dec. 13, 1894.

————. *Small Electric Light Stations.* An article on the expenses of running a small electric plant, with suggestions for its management. By J. E. Talbot. *Eng. Mag.*, Feb., 1894.

————. *The Monocyclic Alternating System.* The alternating induction motors having an auxiliary circuit devised for use where both lighting and power are desired. *Elec. World*, Oct. 13, 1894.

————. See *Accumulators, Arc Lamp, Armatures, Fuse-Arrester, Batteries, Car, Carbon, Circuit, Condenser, Conductor, Corrosion, Cotton-Mill, Cranes, Current, Dynamo, Electric Lighting, Electric Locomotive, Electric Motors, Electric Power, Electric Railway, Elevators, Energy, Engines, Fuses, Fuse-Arrester, Grass, Insulation, Iron, Lighting, Lighting-Arrester, Magnetic Fields, Magnetic Leakage, Mining, Motor, Navigation, Polyphase Apparatus, Power, Power Plant, Reactance, Sanitation, Smelting, Street Lighting, Transmission, Water Purification, Welding, Windmills, Workshops.*

Electric *Braking.* Theoretical discussion of application to motor cars by W. Nelson Smith. *St. Ry. Gaz.*, Dec. 22, 1894, *et seq.*

———— *Cutout.* The Van Vleck service end cutout. Illustrated. *Elec. Eng.*, Nov. 28, 1894.

———— *Driving.* Discussion of the applicability and economy of electricity to the production of power for general purposes. *Sci. Am. Sup.*, Nov. 17, 1894.

———— *Measuring Instruments.* Standardizing instruments by the potentiometer method, and description of an improved direct reading potentiometer, by Elmer G. Willyoung. *Trans. A. I. E. E.*, Oct., 1894.

———— *Steep-Grade Traction.* Different European lines discussed, working by simple adhesion up to eight per cent., and by aid of a rack-rail for the higher grades. *Elec. Rev.*, Nov. 30, 1894. *St. Ry. Gaz.* Dec. 22, 1894.

———— *Battery. The Chloride Electrical Storage Battery.* Report of committee on science and arts of Franklin Institute. Illustrated. *Power*, Nov., 1894.

———— *Brake. The Sperry* —— *in Chicago.* Illustrated and described. *St. Ry. Rev.*, Aug., 1894.

Electric Lighting.—Continued.

——— *of Railroad Trains.* Expense of equipment and operation by different companies given and compared. *R. R. Gaz.*, July 27, 1894. *Ry. Age*, Aug. 3, 1894.

———. *Specifications of Arc Street Lighting of Detroit, Mich.* Very complete. *Eng. News*, March 1, 1894.

———. *Station of the Citizens' Light and Power Co., of Rochester, N. Y.* By Robt. Cartwright. *Trans. A. S. C. E.*, March, 1890, Vol. XXXI. *Eng. News*, March 8, 1894.

———. *Town Refuse Disposal and ——.* Its economical possibilities discussed by Thomas Tomlinson, Assoc. M. Inst. C. E. *Eng. Mag.*, July, 1894.

———. See *Incandescent Lamps, Light, Railroads.*

Electric Locomotive. A short illustrated popular article. By Geo. L. Clark. *Cassier*, April, 1894.

———. *Recent designs for ——.* Editorial. *Eng. News*, March 15, 1894.

———. *Description of an ——.* Horizontal compound steam engine operates a three-face dynamo, which in turn drives eight motors, each sixty horse-power, driving a single axle. Locomotive weighs about one hundred tons and can develop a speed of over a hundred miles per hour. Illustrated. J. J. Heilman. *Mems. Soc. Ing. Civ.*, Jan., 1893.

———. *Development of the ——.* Illustrated historical account. By B. J. Arnold, M. Am. Inst. E. E. *Eng. Mag.*, July, 1894.

——— *of High Speed on the Paris, Lyons and Mediterranean Railroad.* Illustrated. *R. R. Gaz.*, May 4, 1894.

———. *The Patton independent —— ——.* *Eng. News*, June 14, 1894.

——— *for the Baltimore Belt Railway.* Interesting description of the locomotives, and of the engine and boiler houses, and wiring. *Eng. News*, Nov. 29, 1894.

Electric Motors. *Some Applications of ——.* The applicability and advantage of the motor for capstans, cranes, mills and manufactories, and other such uses. *Elec. Rev.*, Oct. 5, 1894, *et seq.*

———. *The Present Utility of —— on Railroads.* By David L. Barnes. Abstract of paper read before the Western Railway Club. Diagrams and curves. *Eng. News*, May 3, 1894. *R. R. Gaz.*, May 4, 1894.

Electric Plant *at Dresden,* for the use of the Government railways. Illustrated description by Robert Grimshaw. *Elec. World*, Nov. 3, 1894.

———. *The Pittsburg Reduction Company's —— at Niagara Falls.* Description of machinery. *Elec. Eng.*, Aug. 15, 1894.

Electric Power. Isolated storage battery plant at Montreal, Can. Illustrated. *Elec. Eng.*, Nov. 14, 1894.

——— *at the World's Fair.* A popular presentation of interesting information on the use of. By Nelson W. Perry, E.M. *Eng. Mag.*, Dec., 1893.

——— *for Farm Use.* Account of the use of electric power for threshing, grinding, pumping, churning and other farm work near Catasauqua, Pa. *St. Ry. Rev.*, Nov., 1894.

——— *in the Iron Industries.* Paper by D. Selby-Bigge, describing its wide applicability to this field in England. *Eng. Mag.*, Dec., 1894.

——— *Losses.* Wm. S. Aldrich investigates the losses in the transmission machinery of central stations. *Elec. Rev.*, July 6, 1894, *et seq.*

——— *on the Chicago City Railway.* Account of the replacement of steam plant by an electric motor. *St. Ry. Rev.*, Aug., 1894.

——— *Station.* The Ridgewood Power Station, Brooklyn, illustrated and described. *St. Ry. Gaz.*, Nov. 24, 1894.

——— *Station. Non-Arcing Lightning Arresters.* Details of experiment on a 3000-volt alternating current circuit, of a system for protection on circuits of any potential, and consideration of an arrester to stop only the dynamo current. Alexander Jay Wurtz. *Tech. Quart.*, July, 1894.

———. *The Economics of ——.* A very interesting and well-illustrated article by H. L. Lufkin, M. Am. Inst. E. E. *Cassier*, March, 1894.

——— *Transmission.* General discussion of electric energy and its transmission. By Louis Bell. *Elec. World*, Nov. 10, 1894, *et seq.*

Electric Railway.—Continued.

———— *System of Wheeling, W. Va.* A short description of the power plant and track equipment. *St. Ry. Jour.*, April, 1894.

———— *System for London.* J. H. Greathead describes his proposed underground system. *Eng. Rev.*, Aug., 1894, *et seq.*

———— *System of Toronto, Canada.* Illustrated. *Elec. Eng.*, Nov. 21, 1894.

————. *Tests of a Small —— Plant.* Giving tests and results at power plant of Wyandotte and Detroit River R. R. By Jesse M. Smith. *Eng. News*, July 12, 1894.

————. *The Boynton Bicycle ——.* General description and discussion. *St. Ry. Gaz.*, Aug. 25, 1894. *Elec. Rev.*, Aug. 10, 1894. *Elec. Eng.*, Aug. 22, 1894.

————. *The Cass Avenue and Fair Grounds Railway, St. Louis.* A description of the power-plant. Has a Corliss engine, 18 x 36, that makes 150 revolutions per minute. Uses down-draft boilers. *St. Ry. Jour.*, Dec., 1893.

————. *The Douglas and Laxey ——.* Description of this English tramway of about seven miles in length, and maximum grade of 5 per cent., and of the electric equipment, including accumulators. *St. Ry. Gaz.*, Sept. 8, 1894. *Elec. Rev.*, Aug. 24, 1894.

————. *The Hillside Loop on the North Hudson County Railway, New Jersey.* A vertical ascent of 160 feet in a horizontal distance of 180 feet. Illustrated. *R. R. Gaz.*, March 16, 1894.

————. *The Liverpool Overhead ——.* Valuable technical information in regard to operating, equipment, efficiency of ——. Traction diagrams given. *R. R. Gaz.*, March 16, 1894.

————. *The Motive Power Required for an ——.* As computed for the line from Lyons to Oullins, France. *Am. Eng. & R. R. Jour.*, Aug., 1894.

————. *The South Staffordshire ——.* Description of this English line, by Alfred Dickinson. Assoc. M. Inst. C. E. *Proc. Inst. C. E.*, Vol. 117.

————. *The Wyoming Valley ——.* Illustrated. *St. Ry. Jour.*, Dec., 1894.

———— *Underground System.* The Electro-Magnetic Traction Company's System, where the power is obtained by means of energizing and collecting bars on the car, making contact with corresponding plates in ground fifteen feet apart. Illustrated. *Lon. Eng.*, Dec. 7, 1894. *Elec. Eng.*, Nov. 28, 1894. *St. Ry. Gaz.*, Dec. 1, 1894.

————. See *Street Railway, Elevated Railway, Guard Wires, Motor, Power-Plant, Rack Railway, Rail Cleaning, Rails, Street Cars, Transition Curves.*

Electric Railways. New System of J. J. Heilman. Ordinary railroads to be used. Locomotive replaced by a car provided with a triple expansion engine and generator. This car has a prow-shaped front and a smooth iron covering. Each following car in train has a motor fed by above generator. Illustrated. *Mems. Soc. Ing. Civ.*, Feb., 1891.

————. *City and Suburban.* Report of committee of American Street Railway Association, read at Atlanta Convention, Oct. 17, 18, 19, 1894. By L. C. Foster. *St. Ry. Jour.*, Nov., 1894.

———— *Compared with Cable Railways.* Comparative working expenses of two British lines. *Elec. Rev.*, Sept. 7, 1894.

———— *Conduit ——.* Joseph Sachs, Assoc. M. Am. Inst. E. E., gives its present status and describes many different systems. *Cassier*, Sept., 1894.

————, *Conduit System of ——.* A short description of the Munsie-Coles conduit system, operated in Hartford, Conn., for almost a year. *Elec. Eng.*, Feb. 14, 1894.

————. *Importance of Complete Metallic Circuits for ——.* An interesting article discussing the effects of incomplete circuit; as fires, electrolysis of water pipes, etc. By J. H. Vail, M. Inst. Elec. Eng. *Eng. News*, March 15, 1894. *Cassier*, June, 1894.

———— *in the United States and Canada*, as investigated during the World's Fair. Critical discussion by H. D. Wilkinson. *St. Ry. Gaz.*, Nov. 17, 1894.

————. *Overhead Trolley System* briefly discussed. By O. M. Rau. *Cassier*, June, 1894.

————. *Rail Bond for ——.* Design of A. L. Johnston. *Eng. News*, June 14, 1894.

————. *Requirements for ——*, as given by the English Board of Trade. The object is to prevent injury to underground pipes. *Eng. News*, May 3, 1894.

————. *Return Circuit for ——.* Abstract of a paper read before the New Orleans Electric Society, by H. J. Malachee. *St. Ry. Rev.*, April, 1894.

————. *Some Practical Points in the Construction of Underground Feeders.* A paper by Dugald C. Jackson, in which are discussed the various kinds of conduits. Annual cost (interest, depreciation and maintenance) said to be three or four times that of good overhead construction. *St. Ry. Jour.*, Dec., 1893.

Falls of the Missouri. See *Water Power.*

Factories. *Profit-sharing and Co-operation in* ——. An article entitled "Through Profit-sharing to Co-operation," by N. O. Nelson, in *Employer and Employed. Am. Mach.*, Feb. 8, 1894.

Fans *for Ventilating Mines.* Paper by G. Herbst, giving their theory and results of tests. Illustrated. *Ztsch. Ver. Ing.*, Sept. 15, 1894.

————. *Notes on Efficiencies of* ——. Article by William Sangster, giving results of experiments made on two fans. *Am. Mach.*, July 19, 1894.

Fence-Posts. *Pressed Steel* ——. Illustrated description. *R. R. Gaz.*, Nov. 9, 1894.

Fender *for Street Cars.* Designed by H. N. Eaton. Illustrated. *St. Ry. Jour.*, Dec., 1894.

————. *for Street Cars.* Tests, showing the efficiency of the Modemann fender, made by a Brooklyn electric line, described and illustrated. *St. Ry. Gaz.*, Oct. 13, 1894.

———— *for Street Cars.* The Blakistone fender, used for a year at Baltimore. The Modemann successfully tested at Brooklyn. The Pittsburg McGuire fender. Illustrated. *St. Ry. Rev.*, Dec., 1894.

Ferris Wheel. *Calculation of Stresses in* ——. A method given by J. W. Schaub, C. E. *Eng. News*, March 22, 1894.

———— *Stresses in* ——, *Three Methods for Computation of* ——. By E. Gerber, J. W. Schaub and H. H. Wadsorth. *Eng. News*, April 26, 1894.

————. *The Construction of* ——. A paper by W. H. Searles, M. Am. Soc. C. E. Read before the Engineers' Club of Cleveland. *Jour. Assn. Eng. Socs.*, Dec., 1893.

Ferryboat *of To-day.* An extensive article on the construction and efficiency of the New York ferryboats by Col. Edwin A. Stevens. *Transactions of the Society of Naval Architects and Marine Engineers*, 1893. *R. R. Gaz.*, June 26, 1894. *Cassier*, Aug., 1894.

————. *The Design of the* ——. Current English and American practice, illustrated and described. *Eng. News*, Sept. 13, 1894.

Ferryboats. *Recent Types of* ——. Andrew Brown writes of the different English and American types of ferryboat. *Proc. Inst. C. E.*, Vol. 118.

————. *The Birkenhead* ——. General Description of the English boats "Wirral" and "Mersey," by Charles Jones. *Proc. Inst. C. E.*, Vol. 118.

Ferry Transfer. *The Hobb's Island* ——. Description, with plan, profile and detail drawings. Built to be adapted to a rise or fall of 40 feet in the Tennessee River. Length, 1,370 feet, 3½ per cent. grade. *R. R. Gaz.*, Jan. 26, 1894.

Filter. *Mechanical* ——, *at New Orleans.* F. W. Cappelen describes this filter of fourteen million gallons daily capacity, and the proposed filter for Minneapolis. *Eng. News*, Aug. 30, 1894.

————. *The Comparative Cost of Mechanical* —— *and Sand Filter Beds.* Several opinions. *Eng. News*, Aug. 16, 1894.

————. See *Water Works.*

————. Paper, giving data concerning various filter beds, by James B. Rider. *Eng. Rec.*, Sept. 1, 1894

————. *Continuous and Intermittent Sand* ——. With its efficiency in regard to the removal of bacteria, as illustrated by the works at Lawrence, Mass. By George W. Fuller. *Eng. News*, Oct. 4, 1894. *Eng. Rec.*, Oct. 6, 1894.

————. *in America.* Results and table from the Lawrence experiments, showing the amount of sand which must be removed from the filter bed in order to prevent clogging. *Eng. News*, Nov. 29, 1894.

Filtration. See *Water Works.*

————. *The Filter of the City of Lawrence, Mass.* Explanation and discussion of the construction of the sand filter beds by Hiram F. Mills. *Jour. N. E. W. W. Assn.*, Sept., 1894. *Eng. Rec.*, Dec. 30, 1893.

————. *The* —— *of Water at Providence, R. I.* Mechanical and slow filtration compared. By J. Herbert Shedd. *Eng. Rec.*, July 21, 1894. *Eng. News*, July 19, 1894.

————. See *Sewage, Water Purification, Water Works.*

Fire. *Prevention of* ——. The Campbell fire cistern. Illustrated description. *Eng. Rec.*, May 26, 1894.

———— **Clays.** *Refractoriness of* ——. Experiments to determine ——, by H. O. Hofman and C. D. Demond. Theoretic and experimental methods. Well illustrated. *Tech. Quart.*, Dec., 1893, Vol. VI.

Gas.—Continued.

———. *Engine.* Its modern development and applicability and efficiency shown by James Atkinson. Illustrated. *Lon. Eng.*, Nov. 30, 1894. *Prac. Eng.*, Nov. 30, 1894, *et seq.*

——— *for Fuel.* A paper by Donald McDonald before the Ohio Gaslight Association, comparing the cost of artificial gas as a fuel with the cost of other fuels. Extracts. *Eng. News*, May 31, 1894.

———. *Fuel* ——. The American Gas Furnace Company's System and Apparatus. Report of the Committee on Science and the Arts. *Jour. Frank. Inst.*, Nov., 1894.

———. *Indiana's Natural* ——. Report of State Gas Inspector Jordan. *Iron Age*, Aug. 23, 1894.

———. *Heating by* ——. Series of articles by H. Meidinger, treating the subject from a practical standpoint. *Jour. f. Gasb. u. Wasserv.*, Sept. 10, 1894, *et seq.*

——— *in the United States.* Illustrated articles by W. von Oechelpouser describing this industry. *Jour. f. Gasb. u. Wasserv.*, Sept. 1, 1894.

——— *Motors.* By Auguste Moreau. An illustrated historical and descriptive article. *Mêms. Soc. Ing. Civ.*, Oct., 1891.

——— *for a Street Railway.* See *Street Railway.*

———. *Plant. Motor* ——. Arrangement to effect the use of soft coal for fuel in connection with the gas engine, without the choking of the tarry ingredients. *Eng. Rec.*, Dec., 1894.

——— *Power.* Its efficiency, utility and scope. The wide and growing field of the gas engine. J. Emerson Dowson. *Eng. Rev.*, Nov., 1894, *et seq.*

———. *Prepayment Gas Meter.* An illustrated description of a new meter on the principle of the penny-in-the-slot machines. *Jour. f. Gasb. u. Wasserv.*, May 1, 1894.

———. *Producer* ——. The advantages of producer gas for steam raising considered in the way of economy, efficiency and smokelessness. *Cassier*, Dec., 1894.

——— *Tank.* Three-lift gas tank, with a capacity of about six million cubic feet, at the Glasgow Corporation Works. Illustrated. *Lon. Eng.*, Nov. 9, 1894, *et seq.*

——— *Tank. Telescopic* ——. Very full illustrated article by M. Niemann. *Jour. f. Gasb. u. Wasserv.*, Sept. 10, 1894, *et seq.*

——— *Works.* Their construction exhaustively considered by C. Hunt. *Proc. Inst. C. E.*, Vol. 117.

———. *The Production and Application for Power Purposes.* Paper by Boischevalier, read before the Society of the Lower Rhine. The paper considers the subject both from a theoretical and practical standpoint; it is quite comprehensive. *Ztsch. Ver. Ing.*, Nov. 10, 1894.

———. *The Welsbach Burner for Artificial* ——. Short article. *Eng. News*, May 17, 1894.

———. *Water Gas.* By M. A. Levezzari. *Mem. Soc. Ing. Civ.*, July, 1892.

Gasometers. *The Construction of* ——. Paper by P. Pfeifer, read before the German Society of Sanitary Engineers. It treats the subject exhaustively, and is well illustrated. *Jour. f. Gasb. u. Wasserv.*, Oct. 1, 1894.

———. *The Temperature in* ——. Observed daily for a whole year, and the influence of the change of temperature on its expansion. Dr. W. Seybold. *Jour. f. Gasb. u. Wasserv.*, Nov. 10, 1894.

Gears. *The Calculation of Toothed* ——. Practical formulæ for this calculation, taking the friction between the teeth into account, in a rational way, besides the strength of the teeth. *Ztsch. Ver. Ing.*, Oct. 6, 1894.

Generator. *New Mather Railway* ——. Illustrated and described. *St. Ry. Jour.*, Aug., 1894. *St. Ry. Gaz.*, Aug. 4, 1894.

Geodesy. *An Old Geodetic Survey* made in the island of Tasmania, 1849–51. From *The Indian Engineer. Eng. Rec.*, Jan. 27, 1894.

———. *Precise Leveling.* Report upon precise leveling in Europe, giving methods and instruments used in attaining great precision. Also a report upon a datum plan for international elevations. *Comptes Rendus de L'Association Géodésique Internationale*, 1894.

———. *Variation of Latitude at Waikiki, Honolulu.* Report of E. D. Preston, Asst. U. S. C. & G. Survey. *Pamphlet U. S. C. & G. Survey*, T. C. Mendenhall, Supt.

———. See *Base Lines, Surveying, Latitude and Longitude, Precise Levels, Steel Tapes, Triangulation.*

Harbor *and Docks of Southampton.* General description and detailed account of this prominent English port, by John Dixon. *Lon Eng.*, Aug. 24, 1894. *Ry. Eng.*, Oct., 1894. *Lon. Engineer*, July 27, 1894.

———. *Construction of Bilboa* ——. Abstract from article iv *London Engineering.* Illustrated. *Eng. Rec.*, Dec. 16, 1893, *et seq.*

——— *of Tunis.* Natural features and permanent improvements, consisting of jetties and a dredged channel nearly seven miles in length, from the harbor to the city, with maps. Eugene Résal. *Annales des P. & C.*, Oct., 1894.

——— — *Quay Wall.* A method used to secure the stability of a quay wall at the port of Altona, Germany, which had shifted its position after completion, by Berthold Stahl, Germany, for the International Congress of Engineers at Chicago. A descriptive paper accompanied by drawings. *Trans. A. S. C. E.*, Dec., 1893.

Harbors. *Rock Dredging in* ——. A valuable paper by Gius. Cimino and C. Verdinois. Read at the London meeting of the International Maritime Congress. Discussing methods, explosives, etc. *Eng. Rec.*, Feb. 24, 1894, *et seq.*

Harper's Ferry *Improvement.* The new bridge and tunnel and change of alignment with consequent excavations, embankments, trestles and retaining walls of the Baltimore and Ohio, R. R. main line and Shenandoah Valley branch. Wm. Lee Sisson. *Trans. A. S. C. E.*, Oct., 1894.

Haulage by Horses. See *Power.*

Heat *of Oil and Gas Lamps.* An experimental determination of the heat generated per candle-power by oil and gas lamps. By Prof. D. S. Jacobus. Illustrated with diagrams, and tabulated. *Trans. A. S. M. E.*, Vol. XIV, 1893.

———. *Diagrams. Referred to the Saturation Curve.* See *Saturation Curve.*

———. *Specific* ——. A mathematical discussion of negative specific heat. By Prof. De Volson Wood. *Trans. A. S. M. E*, Vol, XIV, 1893.

Heated Air. *Methods and Apparatus for Drying with* ——. Different systems and processes described by E. M. Cook. *Proc. Eng. Club Phila.*, April-June, 1894.

Heating *and Ventilation.* Heat loss through walls of various substances and thicknesses. Table of factors for ——. Article by Alfred R. Wolff. *Jour. Frank. Inst.*, July, 1894, *et seq.*

——— *and Ventilation of a Hospital.* Illustrated. *Eng. Rec.*, April 28, 1894.

——— *and Ventilation of a New Haven Office Building.* Illustrated description. *Eng Rec.*, June 9, 1894.

——— *and Ventilation of School Building, Duluth, Minn* *Eng. Rec.*, May 12, 1894.

——— *and Ventilation of the United Charities Building, New York City.* Brief and illustrated description. *Ztsch. Ver. Ing.*, Sept. 8, 1894.

——— *and Ventilation.* See *Ventilation.*

———, *by Exhaust Steam.* Short description of the system of heating from a central station, in successful operation in Springfield, Ill. *St. Ry. Jour.*, April, 1894.

——— *by Steam.* —— The plan of the New Netherlands Hotel. Illustrated details. *Eng. Rec.*, Dec. 2, 1893.

———. *Hot Water* ——. Gold's system of hot water circulation described and illustrated. *R. R. Gaz.*, June 1, 1894.

———. *Hot Water* —— *of a Church in Danbury, Conn.* Illustrated description. *Eng. Rec.*, June 23, 1894

——— *Light and* —— *Station of University of Pennsylvania.* Short description of the station by Samuel B. Locke. *Eng. Mech.*, June, 1894.

——— *of Public Buildings Abroad.* Description, with cuts of buildings and appliances. *Eng. Rec.*, April 7, 1894.

——— *Plant Tested.* By Geo. H. Barrus. Brief report. *Eng. Rec.*, June 23, 1894.

——— *Power of Smoke.* See *Smoke.*

———. *Required* —— *of Buildings in 70° in Zero Weather.* Mr. Ed. E. Magovern investigates theoretically the problem: If an apparatus can heat a building to 70° in zero weather, to what temperature will the same apparatus heat the building at 30°, 40°, 50° and 60° outside temperature in calm weather? *Eng. Rec.*, Feb. 3, 1894.

Internal Navigation. Report of the Proceedings of the Fifth International Congress, by M. J. Fleury. *Mêms. Soc. Ing. Civ.*, Nov., 1893.

Interlocking Plant *for Grade Crossings of Electric and Steam Railways.* Description of arrangement of the Chicago and North Shore Electric Railway and the C. M. & St. P. Ry. *Eng. News*, Feb. 22, 1894.

——— *System. A New Pneumatic Interlocking* ——. Crossing of the Delaware, Lackawanna and Western and Western New York and Pennsylvania Railways on the outskirts of Buffalo, N. Y. A compressed air system for semaphores, derailing switches, dejector bars and interlocking. Details and description of this simple and well-arranged plant. Uses air at a pressure of only 10 pounds per square inch. *Eng. News*, Dec. 21, 1893. *R. R. Gaz.*, Dec. 29, 1893. *Ry. Rev.*, Dec. 23, 1893.

——— **Systems.** *Electro-Pneumatic and Manual* —— *Compared. Eng. News*, May 24, 1894.

——— *Systems. The Train Staff System and the Electro-Pneumatic Locking Plant.* Description of Webb and Thompson's and the Union Switch and Signal Co.'s exhibits at the World's Fair. *Eng. News*, Jan. 18, 1894.

———. See *Switches.*

Intrenching Tools. *Portable* —— *for Infantry.* By Lieut. W. C. Wren, U. S. A. *Sci. Am. Sup.*, July 28, 1894.

Inventions. *Precautionary Hints for Inventors.* By Frank Richards. *Eng. Mag.*, March 1894.

Iron *Crystallized by Vibration.* The theory advocated by some and denied by others, in the discussion on the molecular structure of stamp stems. *Trans. A. I. M. E.*, 1894. *Eng. News*, Oct. 4, 1894.

———. *Crystallized by Vibration.* The theory again opposed by H. M. Howe. *E. & M. Jour.*, Nov. 24, 1894.

———. *Development of the Railroad* —— *Industry in China.* An account of the rolling mills of Hanyon. *Jour. Soc. Arts*, July 27, 1894.

———. *Malleable* ——. *Tests of* ——. Results of forty-five tests for tensile strength, elastic limit and elongation. *Ry. E. & M.*, Nov., 1894.

———. *Malleable* —— *Castings.* A series of articles by S. Bolland. *Mech. World*, July 6, 1894, *et seq.*

———. *Mechanical Analysis for Controlling Foundry Mixtures for Cast* ——. A paper by W. J. Keep, prepared for the meeting of the Foundrymen's Association at Philadelphia. *Am. Mach.* April 12, 1894, pp. 9-12. See also *Cast Iron.*

———. *Rustless Coating for* ——. Translation of a paper read before the Paris Société d'Encouragement, giving briefly some of the processes for enameling and tinning iron. *Eng. News*, March 22, 1894.

———. *Strength and Resilience of Cast* ——. Abstract of paper by J. B. Johnson, read before the Foundrymen's Association at Philadelphia. *Mech. World*, July 20, 1894.

———. *Sulphur in* ——, and its elimination. A paper by J. E. Stead. Read before the Iron and Steel Institute of Great Britain. Illustrated. Abstract *E. & M. Jour.*, Oct. 15, 22, 29, Nov. 12, 19, 26, and Dec. 9, 1893.

———. *The Action of Electricity on the Carbonization of* ——. John Carnier in the *Comptes Rendus. E. & M. Journal*, Jan. 20, 1894.

———. See *Steel, Iron and Steel, Buildings, Building Construction, Cast Iron, Coal, Column Pipes, Railroad, Tests.*

Iron and Steel. Production in the United States in 1893. *E. & M. Journal*, Jan. 27, 1894.

———. *Coefficients of Resistance.* By M. Contamin. A short article containing extracts from standard specifications of European companies. *Mêms. Soc. Ing. Civ.*, Sept., 1894.

———. *Do* —— *Crystallize in Service?* Paul Kreutzpointner gives reasons for a negative answer. *Eng. News*, July 19, 1894.

———. *Elimination of Sulphur from* ——. The new process, utilizing lime applied in the blast; satisfactory results of preliminary test. *E. & M. Journal*, Oct. 6, 1894.

———. *Microscopic Tests of* ——. See *Microscopic Examination.*

———. *Rustless Coatings for* ——. Different processes described by Matthew P. Wood. *Eng. News*, July 19, 1894. *Am. Mach.*, Sept. 27, 1894, *et seq.* *Lon. Engineer*, Sept. 14, 1894, *et seq.*

———. *Tests on* ——. See *Torsion Tests*; also, *Iron and Steel.*

Iron and Steel.—Continued.

———. See *Dock Gates, Railroad.*

———. See *Microscopic Examination.*

Ironclad. *The Earliest* ——. Historical sketch. By R. H. Thurston. *Cassier*, Aug , 1894.

Iron Ore. *The* —— *Region of Lake Superior.* An illustrated article. *Eng. Mag.*, Dec., 1893.

Iron Wire. *Tests of* —— made at the Mass. Inst. Tech. Full records of some 200 tests of galvanized, of bright, and of enameled iron wire, giving moduli of elasticity. *Tech. Quart.*, Vol. VII, July, 1894.

Ironwork. *Wrought* ——. Historical, descriptive and well illustrated. *Am. Arch.*, Aug. 11, 1894, *et seq.*

Ironworks. *The Atlas* —— at Sheffield, England. Description of machinery and plant, with especial reference to the rolling of armor plate. *Lon. Engineer*, Nov. 2, 1894.

Iron. *Wrought* ——. *Tests of* —— in tension and compression, made at Mass. Inst. Tech. Full records of several hundred tests, giving moduli of elasticity. *Tech. Quart.*, Vol. VII, July, 1894.

Irrigation. The legislative and practical problems to be considered at the Denver Congress. *Irrigation Age*, Aug., 1894.

———. The Denver Congress on ——. Reports from different states; views of members and deliberations; address to the people of the United States; memorial to Congress, and platform advocating certain national and state legislation. *Irrigation Age*, Oct., 1894.

———. *Experiments and Observations in Utah.* Results and studies of the experimental station of the Utah Agricultural College in regard to surface and sub-surface irrigation. *Eng. News*, March 1, 1894.

——— *in the Malay Peninsula.* General statement of the conditions and proposed works in Perak. *Ind. Eng.*, Aug. 25, 1894.

——— *in Western Kansas.* Rainfall, evaporation, irrigation works, and the application of water in the valley of the Arkansas River. By E. C. Murphy. *Kansas University Quarterly*, Oct., 1894.

———. *Module Gate for* ——. Description by R. G. Kennedy of gate designed to give automatically a constant flow of water. *Ind. Eng.*, Sept. 1, *et seq.*

———. *On the Engineering and Practical Features of* ——. By A. M. Van Auken, C.E. *Jour. Assn. Eng. Socs.*, Dec., 1893.

———. *Pumping Water for* —— *in Arizona.* *Eng. News*, May 31, 1894.

———. *Water Supply for* ——. Report in deta l by F. H. Newell, giving results of measurements and investigations of streams in the arid region of the United States, with detailed consideration of the Missouri, Yellowstone and Platte Rivers and their tributaries. *U. S. Geological Survey, Report for 1891-2, Part 3.*

———. See *Canal, Pumping Engine, Pumping Plant, Sewage.*

Jack-screws. *Efficiency of* ——. Results of tests with three different kinds of oil, using ball and plain bearings under the head or cap, etc. Efficiency $= \dfrac{\text{load} \times \text{pitch of screw in inches}}{3.1416 \times 2 \times \text{lever in inches} \times \text{pull.}}$ Tabular results. By E. F. Miller and W. A. Johnson. *Tech. Quart.*, Dec., 1893.

Jet Propulsion *for Steamers.* A discussion of the theory of ——, accompanied by an illustrated description of a German river steamer, the "Sachsen," of considerable size, thus propelled. *Eng. News*, June 21, 1894.

Jetties *at Tampico, Mexico.* Brief description of some of the results accomplished by ——. *Eng. News*, May 31, 1894.

———. *Mississippi River* ——. Article on the reported shoals at ——. *Eng. News*, May 3, 1893.

———. See *Sea-Walls.*

Labor. *The Relations of Employer and Workman.* Compulsory arbitration wrong in principle. Discussion and arbitration profitable. Address by Hon. Carroll D. Wright. *Am. Arch.*, Aug. 18, 1894.

———. *Laboratories.* An illustrated description of the hydraulic laboratory of the Massachusetts Institute of Technology. By Prof. Dwight Porter. *Jour. N. E. W. Assn.*, Dec., 1893.

Laboratories. Engineering ——. By Prof. R. C. Carpenter. Short article. *Science*, Nov. 3, 1893.

Limes and Cements. *Testing of* ——. Reports of the conferences (of engineers and manufacturers of Dresden, Munich and Berlin, on the uniformity of methods of testing materials of construction, especially those concerning limes and cements, by M. E. L. Candlot. *Mém. Soc. Ing. Civ.*, Feb. 1891.

Limestone *as a Building Stone.* By T. C. Hopkins. *Stone*, July, 1894.

Link Motion. An interesting article by J. E. Johnson. Illustrated. *Eng. News*, June 14, 1894.

Liquefaction and Solidification. *The* —— *of Air and Gases.* By Henry Wurtz, Ph.D. *Sci. Am. Sup.*, July 14, 1894.

Liquid Fuel *for Locomotive.* See *Locomotive.*

Lithium. *Preparation of Metallic* ——. Mr. Guntz, in the *Comptes Rendus*, Dec. 29, 1893. Abstracted in *Eng. and Min. Jour.*, Jan. 27, 1894.

Lithographic *Stone.* Localities of —— and the quarries of Bavaria described and the occurrence and characteristics of this finest of lithographic stones given. *Sci. Am. Sup.*, Nov. 24, 1894.

Locks *for Canals.* Paper by Freytag, read before the Society of Engineers at Mannheim. A review of modern practice, giving both the ordinary methods of constructing locks and the more modern method of lifting the ships by mechanical power. *Ztschr. Ver. Ing.*, Nov. 10,1894.

————. *Foundations of* ——. Stopping leaks by compressed air. Short article. *Eng. News*, May 10, 1894.

Locomotive. Six-wheel tank engine for Ducktown Copper Mines described and illustrated. *Eng. News*, June 14, 1894.

————. *Boilers, Brass and Copper Tubes for* ——. Specifications and record of tension tests for Antofagasta Railroad, Chili, S. A. *R. R. Gaz.*, Jan. 19, 1894.

————. *Compound* ——. *Saving Effected by Compounding.* By C. H. Quereau, Engineer of Tests of C. B. & Q. Railroad, cites a saving of 15 per cent. of coal over the best record of a single cylinder engine of same class. *Am. Eng & R. R. Jour.*, March 1894.

————. *Compound Freight* ——. Cuts and principal dimensions of a compound Mogul engine, built by the Pittsburg Locomotive Works. *Am Eng. & R. R. Jour.*, Feb. 1894.

————. *Compounding of* ——. A modification of the Von Borries system. Illustrated description. *R. R. Gaz.*, May 11, 1894.

———— *Cylinder and Frame Fasteners.* Abstracted from a report presented to the Southern and Southwestern Railway Club. Twenty-one illustrations. Calling attention to bad practice and recommending certain standard practice. Many valuable and practical recommendations are made by the committee. *Ry. Rev.*, Jan. 20-27, 1894.

———— *Designing of the* —— *on German Railroads.* By E. M. Herr. *R. R. Gaz.*, Aug. 10, 1894.

————. *Development of the Compound* ——. Mainly historical. By A. Von Borries, Germany. *Trans. A. S. M. E.*, Vol. XIV, 1893. *Cassier*, June, 1894.

————. *Electric* ——. See *Electric Locomotive.*

————. *Engine Truck Side Bearings* ——. New York and Hudson River Railroad Engine No. 999 at World's Fair, with drawing. *R. R. Gaz.*, Jan. 12, 1894.

———— *Fire Box, Expansion of* ——. Detailed account of experiments on fire boxes of locomotives by the Western Railway Company of France, with results. *Am. Eng. & R. R. Jour.*, March, 1894.

————*for Liquid Fuel.* Passenger locomotive of 42 tons weight, 7 feet driving wheels and 18 inch cylinder, with 2 feet stroke, designed for burning liquid fuel on the Great Eastern Railway, England. *Lon. Eng.*, Dec. 14, 1894.

————. *Four Cylinder Compound* ——, *Vauclain Type.* Report of performance of engine exhibited at World's Fair. Illustrated. *R. R. Gaz.*, May 11, 1894.

———— *Injectors.* See *Injectors.*

————. *Internal Friction of the* ——. With table giving probable range of eight-wheel locomotives for speeds from 80 to 130 revolutions. *R. R. Gaz.*, Aug. 3, 1894.

————. *Performance of Two-Cylinder Compound* —— *of the C. C. C. & St. L. Ry. Eng. News*, May 10, 1894.

————. *Reversing Gear for the* ——. A fluid pressure reversing gear illustrated and described by David Joy. *Proc. Inst. Mech Engrs.*, April, 1894. *R. R. Gaz.*, Sept. 28, 1894. *Sci. Am. Sup.*, May 5, 1894.

Hydraulic Machinery for Moving Guns. Hydraulic Appliances in Boiler Construction. Notes on the Machinery of War Vessels. Problems Confronting the Designer of Naval Machinery. The Strength of Ships. Practical Stability. Information. Diagram of Stability. Liquid Fuel on Steam Vessels.

Vol. II.—Coil and Tubulous Boilers. Standard Steam Engine Indicator. Planning and Equipment of Ship and Engine Building Plant. Ice Yachts. Boiler Feeding. Speed Trials. Speed and Revolution Recorder. Coasting and Sailing Vessels of the Adriatic. Steel Castings for Marine Machinery. Tests of Iron and Steel. Steam Shipping of the Great Lakes. Steamers of the Great Lakes Compared as Regards Strength. Western River Steamers. Government Inspection of Merchant Vessels. Rules for Boiler Construction. Cocks on Water-Gages. Forced Draught. Effect of Forced Draught in Causing Leaky Tubes. Valves and Valve-Gears for High Speed Engines. Screw Propulsion.

Markets. *The Covered —— of Europe.* A general description and discursive article. *Lon. Eng.*, June 1, 1894.

Masonry *Conduit* for steam pipes built at cost of $1.95 per linear foot. By J. L. Bauer. *Eng. News*, Nov. 8, 1894.

——— *Lining at Mullan Tunnel.* See *Tunnel.*

——— *of the Cheat River Bridge.* Natural conditions, and plans and details of construction, By Cecil B. Smith, A. M. Can. Soc. C. E. *Trans. Can. Soc. C. E.*, Oct.-Dec., 1893.

———. *Preservation of —— Walls.* Paraffine applied to the walls of the tall office building of the Continental Insurance Co., New York. *Eng. Rec.*, March 31, 1894.

———. *Repair of Bad Joints in Granite by use of Type Metal.* Work done on the piers of the dome tower of the Capitol at Hartford, Conn. An ingenious method. Illustrated. *Eng. Rec.*, June 16, 1894.

———. *Repair of the Moline Wall.* Reinforcement of disintegrated portions of wall by plank facing backed by concrete. *Eng. Rec.*, Nov. 17, 1894.

———. *The Effect of Frost on Green ——.* Résumé of Austrian experiments, showing that frost destroys the adhesion except with Portland cement. The addition of salt increases its efficiency. *Am. Arch.*, Nov. 3, 1894.

——— *The Expansion of ——.* Its amounts and illustrations, by Fr. von Emperger. *Eng. News*, Sept. 27, 1894.

———. See *Bridges, Bridge Pier, Building Construction, Caissons, Chimneys, Concrete Cracks, Dam, Flume, Foundation, Locks, Mortar, Pier, Sewer, Stone, Tunnel, Viaduct.*

Master Car Builders. *Convention of —— at Saratoga.* See *Railways.*

——— *Builders' Association. Recent Circulars of ——.* Proposed file case for standard sizes of catalogues. *R. R. Gaz.*, Jan. 26, 1894.

Mathematics *and its Relation to Engineering.* The "James Forrest" lecture of May 3, 1894, by John Hopkinson, M. I. C. E. *Proc. Inst. C. E.*, Vol. 118. *Lon. Eng.*, June 8, 1894. *Eng. Rec.*, July 14, 1894, *et seq.*

——— *in Technical Schools.* Paper by Prof. Mansfield Merriman concerning teachers and text-books on this subject. *Eng. Rec.*, Sept. 29, 1894.

———. *New Rules for Approximate Integration.* F. W. Durand, Member American Society Civil Engineers and Principal of School of Marine Construction, Cornell University. A valuable contribution to applied mathematics, furnishing a new and simpler form for "Simpson's rule." *Eng. News*, Jan. 18 *et al.*, 1894.

Measure. *Fundamental Principles of ——.* A paper of historical and descriptive import by T. C. Mendenhall, Superintendent United States Coast and Geodetic Survey, before the International Engineers' Congress at Chicago. *Trans. Am. Soc. C. E.*, Oct., 1893.

Mechanic Arts *and Modern Education.* Lecture by Prof. R. H. Thurston, ably and clearly discussing their interdependence. *Sci. Am. Sup.*, Nov. 3, 1894.

Mechanical Engineering. *Meeting of the Am. Soc. M. E. at Montreal.* Extracts from proceedings. *Eng. News*, June 14, 1894.

Mechanical Stokers. *See Boilers* and *Stokers.*

Mechanical Training. *The Critical Side of ——.* Lecture by Prof. A. B. W. Kennedy. *Lon. Eng.*, Aug. 17, 1894. *Lon. Engineer*, Aug. 17, 1894. *Mech. World*, Aug. 17, 1894. *Eng. News*, Aug. 30, 1894. *Sci. Am. Sup.*, Sept. 1, 1894. *Eng. Rec.*, Sept. 15, 1894. *R. R. Gaz.*, Sept. 28, 1894.

Mortar. *The Hardening of* ——. Tests showing that the hardening of lime mortar is due only to the change from calcium hydrate to calcium carbonate, the supposed formation of calcium silicate not occurring. *Eng. News*, Nov. 22, 1894.

————. See *Cements*.

Mortise Gear. *Cogging a* ——. Illustrated article. By James F. Hobart. *Am. Mach.*, Aug. 23, 1894.

Motive Power. See *Railways, Gas*.

Motor. *Electric Railway* —— *Tests*. See *Electric Railway*.

————. *Slow-Speed Dynamo and* ——. Description of slow-speed, four-pole dynamos and motors recently brought out by the General Electric Co. Illustrated. *Elec. Eng.*, Nov. 21, 1894.

————. *Some Facts about the Polyphase* ——. Louis Bell, Ph.D., advocates their advantages. *Elec. Eng.*, Aug. 15, 1894. *Trans. A. I. E. E.*, Nov., 1894.

————. *The Electric* ——. A lecture by Prof. F. B. Crocker, delivered before the Franklin Institute. *Jour. Frank. Inst.*, May, 1894, *et seq.*

————. *The Two-Phase* ——. Experiments for obtaining the current and electro-motive force curves by Dr. Louis Duncan, S. H. Brown, W. P. Anderson and S. Q. Hayes. *Trans. A. I. E. E.*, Nov., 1894.

————. *The Use of the Electric* —— *for Driving Machine Tools.* Discussion, and limited extent of use. *Eng. News*, Aug. 9, 1894.

————. *Capacity of Railway* ——. A short article by E. A. Menill, with table showing pull at periphery of wheel at rated horse-power and speed, and tons per horse-power. *Elec. Eng.*, March 14, 1894.

————. *Using Cylinders and Pistons.* A well written article by W. Lorenz, who tries to prove that the relation between the indicated and effective work of a motor can be expressed by the formula of Pambour. *Ztsch. Ver. Ing.*, Oct. 27, 1894.

———— *Repairing of* ——. Illustrated article by Jas. F. Hobart, on testing and repairing street car motors. *St. Ry. Jour.*, Dec., 1894.

————. *Rotatory Field* ——. Elementary theory, resultant magnetic flux and starting torque if the impressed field is limited. Silvanus P. Thompson. *Elec. World*, Dec. 22, 1894.

————. See *Canal, Gas, Petroleum Motor*.

Movable Dams. See *Great Kenawha Improvement*.

Municipal Engineering. *Engineers as Commissioners for Public Works.* Address by Carl Schurz before a national conference of municipal officers at Philadelphia. He argues that the head of the city engineering department should be an engineer. *Eng. News*, Feb. 1, 1894.

————. *Management of a City Engineer's Office.* A paper read before the Boston Society of Civil Engineers by Geo. A. Kimball. *Eng. Rec.*, Feb. 3, 1894. A paper before the same society by F. Noyes. *Eng. Rec.*, Dec. 30, 1893.

————. *Notes from City Engineers' and other Municipal Reports.* Many valuable data presented in very concise form. *Eng. News*, Feb. 15, 1894.

————. *Some Experiences of a City Engineer in a Small City.* Paper before Indiana Engineering Society, by C. G. H. Goss, City Engineer of Martinsville, Ind. Popular description of the difficulties encountered. *Eng. Rec.*, Jan. 20, 1894.

————. *The Office of City Engineer.* Editorial presenting the first instalment of statistics gathered from different parts of the country, embracing eighty-nine city engineers. *Eng. News*, Feb. 1, 1894.

————. See *City Engineer's Office, Streets, Surveying, Pavements, Paving Roads, Streets, Sanitation, Sewage, Sewer, Sewerage, Subways*.

Nails and Drift Bolts. *Experiments to Determine Holding Power of* ——. Thesis of F. W. Clay, C.E., 1893, Cornell, awarded second prize in *Engineering News* thesis competition. A valuable series of experiments with results ably presented. Contains much of practical value to users of nails and drift bolts. Wire nails do not hold as well as cut nails. Round bolts to be preferred to square. *Eng. News*, Jan. 11, 1894.

Naphtha. *Production of* —— *in Russia.* Article by F. Thiess, based upon Russian sources, giving statistical and other information regarding this important industry. *Jour. f. Gasb. u. Wasserv.*, Dec. 1, 1894.

Power *Absorption.* See *Circular Saw.*

——. *Animal ——, as Applied to Carriages and Vehicles.* A novel and interesting paper entitled "Haulage by Horses." Illustrated with instructive diagrams by Thomas H. Briggs, of England. *Trans. A. S. M. E.*, Vol. XIV.

——. *Electrical Transmission of —— from Niagara Falls.* Abstract of paper read by Prof. George Forbes, before Inst. of Electrical Engineers, London. *Elec. Eng.* Dec., 20, 1894, *et seq.*

——. *Its Generation, Transmission and Use.* President's address by Prof. Alexander B. W. Kennedy, of the Institution of Mechanical Engineers. *Proc. Inst. Mech. Engrs.*, April, 1894. *Eng. Rec.*, July 28, 1894, *et seq.*

——. *Notes on Electric ——.* Paper by D. Selby-Bigge, discussing the cost and efficiency of electric transmission of power. *Prac. Engr.*, Oct. 5, 1894.

——. *Transmission of ——.* A paper by W. A. Anthony, on the conditions of economy in long distance transmission of power by electricity. *Elec. Eng.*, May 30, 1894.

——. *Transmission of —— by Electricity.* An estimate by Edwin J. Houston and A. E. Kennelly of the distance to which Niagara water-power can be economically transmitted by electricity. *Elec. Eng.*, May 2, 1894.

——. *Transmission of —— by Electricity.* By Francis B. Crocker. A non-technical article. *Eng. Mag.*, June, 1894.

——. *Transmission of —— by Electricity.* Short description of the three-phase transmission plant at Taftville, Conn. Power transmitted 4½ miles. *Elec. Eng.*, May 2, 1894. *St. Ry. Jour.*, May, 1894. *Eng. Rec.*, May 5, 1894

——. *Transmission of Niagara Water ——.* Paper on the distance to which the Niagara water-power can be economically transmitted, by Chas. E. Emery. *Elec. Eng.*, May 23, 1894.

——. *Transmission of ——, with an Analysis of Compound Air Compressors.* General discussion of the theory and advantage of these compressors. By A. E. Chodzko. *Am. Eng. & R. R. Jour.*, Aug., 1894. *Eng. Rec.*, May 5, 1894.

—— *Transmission. Three-Phase Electrical System of ——.* A description of the system in successful operation at Redlands, Cal. Plant installed by the General Electric Company. *St. Ry. Jour.*, Dec., 1893.

——. See *Gas.*

—— *Plants and Water ——.* A paper by John Mackenzie, giving the cost of coal for plants of various load factors, and comparing this with the cost of water-power for plants of same load factors. *St. Ry. Jour.*, Dec., 1893.

Power Plant. *Electric ——.* The Arnold system of construction for ——. Well illustrated description. *Eng. News*, May 19, 1894.

——. *Electric ——.* The economical management of electric power stations discussed by George T. Hanchett. *Elec. World*, Oct. 6, 1894, *et seq.* By Frank H. Pitcher. *Trans. Can. Soc. C. E.*, Jan.-June, 1894.

——. *Electric —— Driven by Turbines at Columbia Mills, Columbia, S. C.* Three-phase system. Large plant. Illustrated description. *Eng. News*, May 3, 1894. *Eng. Rec.*, May 5, 1894.

——. *Electric Switch-Boards.* General description by F. R. Slater. *Power*, Aug., 1894.

—— *in the Realty Building.* General description of —— and location of machinery, etc. Illustrated. *Eng. Rec.*, Dec. 16, 1893, April 28, 1894, and May 12, 1894.

—— *Of Niagara Falls.* Description, with inset sheet of drawings and illustrations of tunnel, etc., and power-house. *Eng. News*, April 26, and May 24, 1894.

—— *of Street Railways.* A valuable paper on the performance of ——. Illustrated. Many data given. Results tabulated. By Wm. A. Pike and T. W. Hugo. *Trans. A. S. M. E.*, Vol. XIV, 1893.

—— *Plant of the Broadway Cable Road.* Fully illustrated. *Eng. Rec.*, March 10, 1894.

—— *of the Grosvenor-Dale Company,* with test of a Wheelock compound engine. Rockwood's system. Illustrated. *Eng. Rec.*, Nov. 3, 1894.

—— *of the Lynn and Boston Railroad Co.* An illustrated article describing the building and power equipments of this road. Corliss engines and water tubular boilers. *St. Ry. Jour.*, Jan., 1894.

Pumping Basin. *Cover for* ——. As designed by Frank P. Johnson and erected over the basin, and the well of 40 feet diameter. *Rep. of City Engineer of Waltham, Mass.*, for 1893.

———— *Engine.* Test of an Allis triple-expansion engine, at North Point Station, Milwaukee, Wisc. Report by R. C. Carpenter, of Ithaca, N. Y. *Eng. Rec.*, Dec. 2, 1892.

————. *Boston Water Works.* Description of Mystic Pumping Engine No. 4, with full-page drawing of same. *Eng. Rec.*, Jan. 27, 1894.

————. *Its Many Points, Faults and Peculiarities.* A series of articles by Ernest W. Naylor, M. Am. Soc. M. E. Articles are of a plain, descriptive character, illustrated. *Fire and Water*, Jan. 6, 1894, *et seq.*

————. *Test of —— at Birmingham (Ala.) Water Works.* Full report. *Eng. Rec.*, Jan. 13, 1894.

————. *The Naylor Cross Compound —— for very High Pressures.* Illustrated. *Iron Age*, April 4, 1894. *Eng. News*, April 5, 1894. *R. R. Gaz.*, April 6, 1894.

————. See *Engine, Test, Water Works.*

————. *Recent practice in* ——. An interesting and valuable paper on this subject by F. W. Dean, M.E. Illustrated. *Jour. N. E. W. W. Assn.*, Dec., 1893.

Punching Tests *with Different Forms of Punches.* Thesis work of Geo. S. Allen. Diagrams showing comparative pressures required by the different punches. *Eng. News*, May 3, 1894.

Quarries. See *Stone, Cableways.*

Quarrying *Methods of the Ancients.* As illustrated by Egyptian and Indian works and monuments. By W. F. Durfee, M. Am. Soc. M. E. *Eng. Mag.*, July, 1894. *Stone*, Dec., 1894.

Rack Railway. *Experiences in Regard to the Operation of the* ——. An interesting and freely illustrated paper by Albert Schneider, Germany. *Trans. A. S. M. E.*, Vol. XIV, 1893.

———— *in Japan.* Complete description, by S. Kikkawa, of the route, character of construction and equipment of this Abt rack railway, rising 1,670 feet in five miles, with illustrations. *Lon. Eng.*, Oct. 19, 1894.

————. *Manitou and Pike's Peak* ——. Detailed illustrated description, by Thomas F. Richardson, of this rack railroad, nearly nine miles long and having an average grade of over 16 per cent. *Jour. Assn. Eng. Socs.*, Aug., 1894.

————. *Pike's Peak* ——. An interesting, popular and well illustrated article on the ascent of this mountain by rail. By Albert Spies. *Cassier*, June, 1894.

————. *The Barmen Electric* ——. Illustrated article describing this line, whose greatest grade is 19 per cent., and the average 10 per cent. *St. Ry. Rev.*, Aug., 1894.

————. *The S. Ellero-Saltino* ——. Description of this central rack railway, by Julian Edward Caccia, Assoc. M. Inst. C. E. *Proc. Inst. C. E.*, Vol. 117. *Eng. News*, Sept. 6, 1894.

————. *The Wengern-Alp* ——, *Switzerland.* By T. Delmar, Ph.D., C.E. Length, 11.1 miles. Grades from 8 per cent. to 19 per cent. Cost $72,072 per mile, with gage of 2 feet, 7½ inches. *R. R. Gaz.*, Feb. 9, 1894.

Radiators. *Condensation in Cast Iron* ——. Tests made by William J. Baldwin, and diagram of curves of condensation. *Trans. A. S. C. E.*, July, 1894. *Lon. Engineer*, Oct. 26, 1894.

————. *Plane and Extended Surface* ——. Details and results of comparative tests, by Profs. J. E. Denton and D. S. Jacobus. *Eng. Rec.*, Sept. 8, 1894.

Rail-cleaning *Machine.* Illustrated description of a German machine for cleaning the rails of a street railway line. *Eng. News*, Oct., 1894.

Rails. *Girder —— in Building Construction.* Description of their use in a building at Steelton, Pa., by H. P. Jones, M.E. *Eng. Rec.*, Aug. 4, 1894.

————. *Manning's Double Life Rail.* Describing the recently patented rail having additional metal on the rail head. *R. R. Gaz.*, July 20, 1894.

————. *Movement of Long* ——. *Experiments on the* ——. Experiments and conclusions of A. Torrey, Chief Engineer of Michigan Central R. R., with diagrams. *R. R. Gaz.*, July 27, 1894.

———— *Proper Bonding of —— on Electric Roads.* Abstract of a paper read before the New Orleans Electrical Society by H. J. Malochee. *St. Ry. Jour.*, April, 1894.

————. *Standard* ——. For stone block paved streets. N. Y. C. & H. R. R. R. through Syracuse, showing iron tram bar attachment to the standard rail, converting it into a tramway rail. Illustrated. *R. R. Gaz.*, Jan. 26, 1894.

Railroad—Continued.

———. *Interlocking Switches.* Illustrated description of the plants at Union Station, Chicago. *R. R. Gaz.*, June 1, 1894.

——— *Location.* A paper dealing with the practical questions of the reconnaissance, preliminary and final location of a railroad. By Michael L. Lynch. Read before the American Society of Civil Engineers. With discussion. *Trans. A. S. C. E.*, Jan., 1894.

——— *Management.* Relations of railroad companies and their employees discussed by Ossian D. Ashley, President of the Wabash Railroad. *Ry. Age*, Aug. 24, 1894.

——— *Management.* Training of higher railway officials. *Arch. f. Eisenbw.*, No. 2, 1894.

——— *Management. Causes of Railway Embarrassment.* Opinions of E. St. John, R. I. & P. Ry., and E. P. Ripley, of Ch., Mil. & St. P. Ry. *Ry. Rev.*, Jan. 27, 1894.

——— *Management. The Question of Rest on Sundays in the Freight Department of the Prussian State Railways.* The conclusion is reached that freight traffic may safely be interrupted on Sundays. *Arch. f. Eisenbw.*, No. 2, 1894.

——— *Master Mechanics' Association.* See *Association.*

———. *Movable Sidewalk at the Chicago Exposition.* An illustrated description. *Sci. Am. Sup.*, Dec. 23, 1893.

———. *Permanent Way of the Pennsylvania* ——. Illustrated description of roadbed and track. *Lon. Eng.*, Oct. 26, 1894.

——— *Practice in Europe.* General impression of the railroads of Italy, Switzerland, Germany, France and Austria. *Ry. Eng.*, Dec., 1894.

———. *Preservation of Ties and Timber on the Southern Pacific Railway.* Burnettizing employed. *Eng. News*, April 26, 1894.

———*Rate Question in England.* By W. C. Acworth. *R. R. Gaz.*, Jan. 19, 1894.

———. *Rebuilding the Pennsylvania* —— *after the June Flood of 1889.* By Joseph T. Richards. *Proc. Eng. Club Phila.*, April–June, 1894.

———. *Roadbed of* —— *Cross-section of the C. C. C. & St. L. Ry.* *Eng. News*, May 17, 1894.

——— *Roadbeds.* Paper giving current practice of different railways, with diagrams of the cross-sections. *Eng. News*, Sept. 6, 1894.

———. *Shops of the C. C. C. & St. L.* —— *at Bellefontaine, Ohio.* Illustrated description. *R. R. Gaz.*, May 11, 1894.

——— *Signals.* See *Signaling.*

——— *Signals. An Historical Sketch of* ——. Lecture by Arthur H. Johnson at Harvard University. *R. R. Gaz.*, Aug. 17, 1894, *et seq.*

——— *Signals. Automatic Fog* ——. Dixon's patent automatic torpedo-placing machine. Illustrated. *Eng. News*, March 29, 1894.

——— *Signals. Block Signals and Interlocking Devices in Illinois.* From the twenty-third annual report of Railroad and Warehouse Commissioners of Illinois. *Ry. Rev.*, Aug. 18, 1894.

——— *Signals. The Block System.* The automatic pneumatic signaling system of the Union Switch and Signal Co. illustrated and described. *Lon. Eng.*, Oct. 12, 1894.

——— *Signals. The Block System.* Abstract of paper by John P. O'Donnell, M. Inst. C. E. *Eng. News*, June 28, 1894.

——— *Signals. Use and Purposes of Distant* ——. Correspondence. *Eng. News*, March 31, 1894.

——— *Signals.* See also *Interlocking System.*

——— *Station and other Improvements Relative to the Abolition of Grade Crossings at Brockton*, Mass. *R. R. Gaz.*, April 13, 1894.

——— *Station at Stockbridge, Mass., on the N. Y., N. H. and H. R. R.* A one-story station, constructed of rubble ashlar masonry. Illustrated description, with a few details. *Eng. News*, Nov. 30, 1893.

——— *Station. New Union* ——, *at Boston.* Illustrated description. *R. R. Gaz.*, May 25, 1894.

——— *Station. New* —— *at Dresden.* Paper by C. Köpcke and C. Klette, of Germany, for the International Engineering Congress at Chicago. Illustrated. *Trans. A. S. C. E.*, Nov., 1893.

Railroads.—Continued.

————. *Cliff Railways.* Description by George Corydon Marks of three British railways using the system of water-balance for motive power. *Proc. Inst. C. E.*, Vol. 116. *Prac. Engr.*, Sept. 21, 1894. *Ry. Rev.*, Aug. 11, 1894.

————. *Economics of* ——. Abstract of address by Col. H. S. Haines at meeting of American Railway Association. *Eng. News*, May 17, 1894.

————. *Electric Lighting of Trains.* MM. G. Dumont and G. Baignères. *Mêms. Soc. Ing. Civ.*, Dec., 1892.

————. *Exhibits of Two Great Railroads at the World's Fair.* A well illustrated article of general historical interest by John C. Trautwine, Jr. *Cassier*, Jan. and Feb., 1894.

————. *Freight Rates of* ——. Short instructive article. *Cassier*, June, 1894.

———— *in Mecklenburg-Schwerin.* Article by Otto Schmidt giving a complete technical and financial history of their origin and development. *Arch. f. Eisenbw.*, Nov., 1894.

————. *Jewett's Composite Car Framing.* Illustrated. *R. R Gaz.*, Jan. 19, 1894.

————. *Light.* ——. Advantages given of narrow gauge lines in sparsely populated districts by J. Walwyn White. *Lon. Eng.*, Dec. 21, 1894.

————. *Light —— for New South Wales.* Discussion of paper by Charles Ormsby Burge, M Inst. C. E. *Ry. Eng.*, Aug., 1894.

————. *Meeting of Master Mechanics' Association.* Extracts from proceedings. *Eng. News*, June 21, 1894.

————. *Modern Signaling of* ——. An article of general interest. By C. A. Hammond, Mem. A. S. C. E. *R. R. Gaz.*, May 11, 1894.

———— *of Japan.* Bridge building on the Government Railways, with discussion of bridge types, with particular reference to economy of spans of various lengths. By C. A. W. Pownall. *Ind. Engr.*, Nov. 24, 1894.

————. *Rail Depression and Strain under Locomotives.* Experiments conducted on the C. B. & Q. R. R. with locomotives of various weights, standing on 66- and 75-pound rails, with oak ties and gravel or cinder ballast, and hard clay bottom. Diagrams of results. *Ry. Rev.*, March 24, 1894, *et seq.*

————. *Recent Experience with Tie Plates.* By Benjamin Reece, C. E., with interesting photographs of ties protected by Servis plate and ordinary flat plates. *Eng. News*, Feb. 22, 1894.

————. *Requisites of a Smooth Track.* By Philip Noonan. An experimental sketch. *Ry. Rev.*, Dec. 23, 1893, *et seq.*

————. *Stationary Materia'.* Report of committee of the Société des Ingénieurs Civils, appointed to study the stationary materials of railroads exhibited at the Paris Exposition of 1889. By M. Ch. Taconnet. *Mems. Soc. Ing. Civ.*, Aug., 1891.

————. *Steam and Electric* ——. Contrasted and compared by Thomas L. Greene. *Eng. News*, June 28, 1894.

————. *Strategic Mountain* ——. The alignment, construction, cost and operation of some remarkable frontier lines of the world. Illustrated. *Lon. Eng.*, Nov. 2, 1894, *et seq.*

————. *Surveys for Railways. Long Tangents.* A method of readjustment of long tangents which usually are not straight lines. By Prof. Wm. D. Pence. *The Technograph*, University of Illinois, 1893-94.

————. *The Improvement of Grades and Alinement, versus Increase in Weights of Locomotives.* By Henry C. Thompson. *Jour. Assn. Eng. Socs.*, May, 1894. *Ry. Rev.*, Aug. 4, 1894.

————. *The Master Car Builders' Convention at Saratoga.* Valuable extracts from the proceedings. *R. R. Gaz.*, June 15 and 22, 1894.

————. *The Prussian State* ——. Comments on ——. *R. R. Gaz.*, June 28, 1894.

————. *The Railroads of Australia.* General consular report by Daniel W. Maratta. *Ry. Rev.*, Aug. 11, 1894. *Ry. World*, Aug. 4, 1894.

————. *The Scale Testing Car of the Pennsylvania Railroad.* *Ry. Rev.*, Feb. 3, 1894.

———— "*Track.*" A paper read on this comprehensive subject before the students of the University of Wisconsin by L. F. Loree, Superintendent of Cleveland and Pittsburg Division of Pennsylvania Lines west of Pittsburg. *Pamphlet, Bulletin of the University of Wisconsin*, Madison, Wis. Extract in *R. R. Gaz.*, May 4, 1894.

Refrigeration.—Continued.

———. *Theoretical and Practical Ammonia.* A series of articles of interest and value by Iltyd I. Redwood, Assoc. Mem. A. S. M. E., appearing in *London Engineer* during winter months of 1893–1894.

Refuse. *Town* ——. Utilization of —— for making steam. Discussion by T. W. Baker, with reference to furnaces, methods and results in England. *Lon. Engineer*, Nov. 2, 1894.

Reservoir. *A Covered* ——. Description and illustration of roof construction of the Rockford. Ill., reservoir. *Jour. Assn. Eng. Socs.*, Sept., 1894. *Eng. Rec.*, Sept. 29, 1894.

———. *A Novel Covered* ——, *of Iron*, supported on cast-iron columns, at Bordeaux, France. The soil was not of suitable character for a reservoir of ordinary type. *Eng. News*, March 22, 1894.

———. *Bursting of the Portland* ——. An illustrated account of ——, by John R. Freeman, C. E. *Jour. N. E. W. W. Assn.*, March, 1894. *Fire and Water*, March 24, 1894.

———. *Construction of ...... Embankments.* By Lucian A. Taylor. *Jour. N. E. W. W. Assn.*, March, 1894.

———. *Covered* ——, *at Brookline, Mass.* Illustrated. By F. F. Forbes. *Jour. N. E. W. W. Assn.*, March, 1894.

——— *Embankments.* See *Embankments.*

———. *Outlet Gates of the Beetalo Water Works* ——. Illustrated. *Eng. News*, March 1, 1894.

———. *Repairs to the Maligakanda* ——, *Colombo. Ceylon.* Cracked concrete walls repaired. Described by Henry Ewart, M. Inst. C. E. *Proc. Inst. C. E.*, Vol. 116, June, 1894. *Eng. News*, Aug. 9, 1894.

———. *The Nile* ——. Discussion of plans. *Lon. Eng.*, June 15, 1894.

———. *The Queen Lane* ——. Details of construction and materials reported on by special committee to the Mayor of Philadelphia. *Eng. Rec.*, Dec. 22, 1894.

Reservoirs. *Covered* —— *at Brookline and Waltham, Mass.* One rectangular, 90 ft. by 100 ft., with roof supported on intermediate pillars, the other circular, 40 ft. diameter, with a dome roof. Details and descriptions. *Eng. News*, Dec. 21, 1893. *Eng. Rec.*, Nov. 28, 1891, and Dec. 16, 1893.

———. *Covered Service* —— *and the Bombay Water Supply.* Paper by Sam. Tomlinson. Bombay Municipality, for the American Water Works Convention at Milwaukee. Illustrated. *Proc. Am. W. W. Assn.*, 1893.

———. *Embankments of* ——. Article taken from the *Jour. N. E. W. W. Assn.* of January. *Eng. Rec.*, May 26, 1894.

———. *Embankments of* —— *and Earth Dams.* By Desmond Fitz Gerald, C. E., New England Water Works Association. *Eng. News*, March 8, 1894.

———. *Storage* ——. The percentage of organic matter at different depths of soil given, to indicate necessary depth of excavation for reservoir beds. *Eng. News*, Nov. 15, 1894. *Eng. Rec.*, Nov. 24, 1894.

———. See *Water Works, Dam, Embankments, Water Supply.*

Reversing Gear *for the Locomotive.* See *Locomotive.*

River *Improvement.* A proposed method of increasing, at critical times, the navigable depth of the upper Ohio River by artificial means. By Thomas P. Roberts. *Proc. Eng. Soc. W. Pa.*, 1893.

———. *Improvement.* Charles River, Boston. Report of commission, including reports of landscape gardeners and of F. P. Stearns, C.E., advocating the improvement of the Charles River for sanitary and æsthetic reasons and for purposes of navigation, by building a dam in the lower part of the river to hold water at about the high water level. *Pub. Doc. No. 775, Mass. Ho. of Rep.*

——— *Improvement.* Historical account of the Clyde, and details of its modern improvement. James Deas. *Eng. Rev.*, Nov., 1894, *et seq.*

——— *Improvement.* Proposal to open an entrance in west breakwater of Cuyahoga River to allow the entrance of the littoral current of the lake for sanitary reasons. Its effects considered by Col. Jared A. Smith. *Jour. Assn. Eng. Socs.*, Nov., 1894.

——— *Improvement of the Danube.* The regulation of the Iron Gate and other cataracts fully illustrated and described by Bela von Gonda. *Lon. Engineer*, June 1, 1894, *et seq.*

River.—Continued.

——— *Improvement. Reclamation of the Potomac Flats at Washington, D. C.* Abstract from a paper by Lt. Col. Peter C. Hains, U. S. Engineer Corps. Read before the American Society of Civil Engineers, Dec. 20. Very concise review of the work done and methods employed with record of quantities moved. *Eng. News*, Jan. 4, 1894. *Eng. Rec.*, Dec. 16, 1893. *Sci. Am. Sup.*, Jan. 13, 1894. *Trans. A. S. C. E.*, Jan., 1894.

———. *Mississippi ——, Floods of the ——.* *Eng. News*, April 19, 1894.

———. *The Missouri ——.* A very interesting description of its physical characteristics by O. B. Gunn, C.E. Read before the Engineers' Club of Kansas City. *R. R. Gaz.*, April 6–13, 1894.

Rivers. *The Training of ——.* L. F. Vernon-Harcourt writes of the improvement of rivers, giving methods followed in different instances. *Proc. Inst. C. E.*, Vol. 118.

Riveted Joints. *Sliding Friction in ——.* Article by C. Bach giving results of experiments as to the friction between plates in riveted joints and the conclusions to be drawn from these results. A valuable contribution to the literature of the subject. *Z. d. V. D. Ing.*, Oct. 20, 1894.

Riveting Pressure. *The Pressure Required for Bridge and Boiler Work.* A valuable and interesting discussion. *Proc. Eng. Club, Phila.*, March 3, 1894. [illegible]

Riveting Shop. *Design of the King Bridge Company's New ——.* Illustrated and described by George E. Gifford. *Jour. Assn. Eng. Socs.*, June, 1894. *Ry. Rev.*, Sept. 22, 1894.

Roads. Suggestions on road-making. By Mr. Arthur Lagrow, City Engineer of [illegible]. *Eng. Rec.*, July 28, 1894.

———. *American Military —— and Bridges.* Historical and descriptive paper by Prof. P. S. Michie, U. S. Military Academy. *Sci. Am. Sup.*, July 21, 1894.

———. *Building of —— in Country Towns.* Short article. *Eng. News*, May 17, 1894.

———. *Carriage-way Pavements for Large Cities.* A paper read before the Society of Arts. A good résumé of English practice. *Eng. News*, March 29, 1894.

———. *Cost of Dirt ——.* Gives cost of a dirt road in Canada. *Eng. News*, May 1[illegible], 1894.

———. *Good Country Roads.* Paper by W. E. McClintock, Member of American Society Civil Engineers, for California Road Convention. Interesting and valuable. *Eng. Rec.*, Dec. 23, 1893.

———. *Good Roads and Rapid Transit Railroads.* A paper calling attention to the damaging effects caused by locating electric and similar roads on the public highways and discussing proper gauge of tracks, the side of the road to be given to the company, how much of the road the company should keep in repair, to what extent it should maintain the bridges, etc. *Deutsche Bztg.*, Oct. 21, 1893.

———. *Harlem River Speedway.* Continuation. *Eng. Rec.*, June 9, 1894.

———. *Hudson County Boulevard.* A full illustrated description of this paved road, which is fourteen miles long, and is to be completely finished, lighted with electricity, and planted with shade trees, etc., for $2,000,000. An interesting piece of engineering. *Eng. Rec.*, March 24, 1894.

——— *of Fairmount Park.* Account of the methods used in building and maintaining the road in this Philadelphia park. *Eng. Rec.*, Sept. 1, 1894.

———. *Road Building in a Southern State.* Short illustrated article on road-making in North Carolina. By D. A. Tompkins. *Eng. Mag.*, Feb., 1894.

———. *Rolling of ...... by Steam Rollers.* A statement of cost and of methods of work done in England. *Eng. Rec.*, June 23, 1894.

———. *Supervision of ——.* See *Highway.*

Roadbeds. *Railway ——.* See *Railroad.*

Road Machines. *Road Machinery at the Columbian Exposition.* Grading machines and ditchers, road rollers, sprinklers and sweepers, rock crushers, etc. Illustrated description. *Eng. News*, Nov. 30, 1893.

Road Rolling Mills, *and Their Development in America.* An interesting paper on this subject. Profusely illustrated. By Fred. H. Daniels. *Trans. A. S. M. E.*, 1894.

Rollers. *Hardened —— for Pressure Bearings.* Discussion of some tests made at Watertown Arsenal, November 19, 1891. *Proc. Eng.*, Nov. 2, 1894.

Sewage—Continued.

————. *Disposal of —— at Canton, Ohio.* Illustrated description of the plant, which is as yet the only one in this State. *Jour. Assn. Eng. Socs.*, Feb., 1894.

————. *Disposal of —— at Chautauqua, N. Y.* Illustrated description of the plant. *Eng. Rec.*, June 24, 1894.

————. *Disposal of —— at Marboro, Mass.* *Trans. Can. Soc. C. E.*, Jan.-June, 1894.

———— *Disposal at Worcester, Mass.* Full illustrated description. *Eng. Rec.*, Jan. 13, 1894.

———— *Disposal Works.* The chemical precipitation works of Chautauqua, N. Y., described in an illustrated article by William B. Landreth, M. Am. Soc. C. E. *Trans. A. S. C. E.*, July, 1894.

———— *Disposal Works, Teddington, England.* Gravity system, aided by Shone ejectors and chemical precipitation works. *Lon. Engineer*, Nov. 2, 1894, *et seq.*

———— *Disposal. Works at Withington, England.* See *Sewerage.*

———— *Filtration. With Special Aeration.* From one of the selected papers of the Institution of Civil Engineers for 1893-4. By Sidney R. Lowcock. Describes experiments with special aeration of the experimental filter tanks. The amount of total ammonias removed was over 99 per cent. *Eng. Rec.*, Jan. 27, 1894.

———— *Irrigation.* Profitable disposal of sewage at Los Angeles, Cal. *Eng. News*, July 5, 1894.

———— *Purification.* Chemical precipitation of sewage at the World's Columbian Exposition. General discussion of results, with tables. *Eng. News*, Nov. 22, 1894.

———— *Purification. Chemical Results from Intermittent Filtration at South Framingham, Marlborough and Gardner, Mass.* Comparison and results of chemical analyses and general methods of filtration. *Eng. News*, Dec. 14, 1893.

———— *Purification in America.* The enlarged chemical precipitation plant at Worcester, Mass. Full illustrated description. *Eng. News*, Jan. 11, 18, 25; Feb. 1, 1894.

———— *Purification in America. Results with Chemical Precipitation at Chautauqua, N. Y.* Cost of operating; analysis. *Eng. News*, Feb. 1, 1894.

————. *Purification of ——.* Chemical results at the Worcester Precipitation Works, with tables of analyses. The Worcester plant is the largest sewage purification plant in this country. *Eng. News*, March 8, 1894.

————. *Purification of ——. Broad Irrigation at North Brookfield, Mass.* Description with plan showing irrigation area and profile of outlet. *Eng. News*, March 22, 1894.

————. *Purification of —— by Filtration.* A paper by Hiram F. Mills, read before the International Engineering Congress at Chicago. *Trans. A. S. C. E.*, Nov. 1893.

————. *Purification of —— in America.* Sewage farm at Oberlin, Ohio. Illustrated. *Eng. News*, June 14, 1894.

———— *Purification. The Partial ——.* By Geo. E. Waring, Jr., M. Inst. C. E. Comments upon chemical processes and describes the effect of a limited flow at the irrigation field at Wayne, Pa. *Eng. News*, Jan. 4, 1894.

————. *Treatment of ——.* Paper by Arthur Bowes concerning the treatment by ferozone and polarite, with details. *Proc. Inst. C. E.*, Vol. 117. *Eng. Rec.*, Sept. 8, 1894. *Eng. News*, Sept. 13, 1894.

———— *Utilized to Furnish Heat for Running an Electric Light Plant.* See *Electric Light.*

Sewer. *A Combined Catch Basin and Manhole for Sewers.* Illustrated description of design by W. S. Shields. *Eng. News*, July 19, 1894.

————. *A Concrete —— on Piles.* By Eugene Lentilhon. *Trans. A. S. C. E.*, June, 1894.

————. *A Piece of Difficult —— Construction.* Description of method used in the semi-fluid soil on Twelfth Avenue, New York. *Eng. Rec.*, July 14, 1894.

———— *Canal Street —— of St. Paul, Minn.* 16 feet section. Description with illustrations, showing pile foundations, etc. *Eng. News*, March 29, 1894.

———— *Construction in Boston, Mass.* General system, with details of standard catch basin and drop inlet, connections and tide-gate chambers. Illustrated. *Eng. Rec.*, Dec. 22, 1894.

———— *Details.* Construction and operation of lamp holes, manholes, drains and cleaning. By A. P. Folwell. *Eng. Rec.*, Nov. 24, 1894.

Sewer.—Continued.

———. *The Discharge of a Circular* ——. Diagrams computed from Kutter's formula by John W. Hill, for cases where diameter, grade, velocity or discharge varies. *Pav. & Munic. Eng.*, Sept., 1894.

———. *Flushing of the Tiber Sewer Outlet, at Washington, D. C.* Description by Capt. Chas. F. Powell, Eng. Com. D. C. Shutter gates impounded the sewage during flood and first of ebb tide. Four million gallons set free at end of ebb. Cost, $600. *Eng. Rec.*, Feb. 17, 1894. *Eng. News*, Feb. 8, 1894.

——— *Manhole.* Illustrated description of a manhole 65 feet deep at Cleveland Ohio. *Eng. Rec.*, May 12, 1894.

———. *Salt Lake Intercepting and Outfall* ——. By W. P. Hardesty. Description, with drawings. *Eng. News*, Jan. 4, 1894.

———. *The Wentworth Avenue Trunk* ——. This Chicago sewer, with methods and details of construction, illustrated and described. *Eng. News*, Oct. 11, 1894.

———. *Tight Sewer Joint.* General method, with plea for pipe sockets of greater length and size. By W. C. Parmley. *Eng. News*, July 5, 1894.

———. *Trench Machine* .... The Moore machine as used on the Green Avenue sewer, Brooklyn, and elsewhere. *Eng. News.*, Dec. 6, 1894.

Sewers. *Cost of* ——. For thirty-inch sewers vitrified pipe claimed to be cheaper and better than brick construction. *Eng. News*, Dec. 20, 1894.

———. *Recent Work on* ——. Giving details of practical construction in several American cities. *Eng. Rec.*, Aug. 4, 1894.

———. *The Sandrock Sewers of St. Paul, Minn.* General description, illustrated. By Geo. L. Wilson, M. Am. Soc. C. E., President Civil Engineers' Society of St. Paul. Abstract from *Trans. A. S. C. E.* *Eng. Rec.*, July 28, 1894. *Trans. A. S. C. E.*, Aug., 1894.

Sewerage. Report upon a system of —— for city of Sioux Falls, S. D. By Rudolph Hering, *Pamphlet*, Jan., 1893.

———, Report upon a system of —— for the city of Superior, Wis. By Rudolph Hering, C. E. *Annual Report of the Board of Public Works of Superior*, 1893.

——— *and Sewage Disposal Works at Withington.* General description and an account of the sewage farm, by Joseph Swarbrick, Assoc. M. Inst. C. E. *Proc. Inst. C. E.*, Vol. 117.

——— *and Water Supply Systems.* Description of the limited but satisfactory systems of Oberlin, Ohio. *Eng. Rec.*, Sept. 29, 1894.

———. *A Study of* —— *Assessments.* Several plans considered. *Eng. Rec.*, June 16, 1894.

——— *of Dartmouth, U. S.* See *Water Works.*

——— *Systems. Recent Metropolitan Work, Boston, Mass.* Description of work, including special description of tunnel under Chelsea Creek. *Eng. Rec.*, Feb. 10, 1894.

——— *System of Brussels.* General and detailed description of the old sewers and the new system. Illustrated. Gibson Thompson. *Pav. & Munic. Eng.*, Nov., 1894.

——— *of Milwaukee, and the Milwaukee River Flushing Works.* Illustrated. Paper by G. H. Benzenberg, M. Am. Soc. C. E., read before International Engineering Congress at Chicago. *Trans. A. S. C. E.*, Nov., 1893.

——— *System of Oberlin, Ohio.* Oberlin is a college town of about 4,400 population and 1,200 to 1,500 students. It owns its water works. *Eng. News*, March 8, 1894.

———. *The Manchester Main Drainage.* William T. Olive describes the conditions existing and the works constructed for intercepting, settling and final disposition of sewage. *Lon. Eng.*, Oct. 19, 1894.

——— *Systems. The Metropolitan* —— *of Massachusetts.* A general description, including a brief review of the investigations which led to its inauguration. From a paper read before the Society of Arts of the Massachusetts Institute of Technology, by Mr. Howard Carson, Chief Engineer. *Eng. News*, Jan. 25, Feb. 8, 1894. *Tech. Quart.*, Dec., 1893. *Eng. News*, May 3, 1893, *et seq.*

———. See *Flush Tank, Syphons.*

Sewer Pipes. *Concussion in* ——. Concussion from blasts at some distance claimed by E. Mohun to have fractured the pipes. *Trans. Can. Soc. C. E.*, Jan.-June, 1894.

Slide Rule. *A Modification of —— for Computation of Bridge Members by the Straight Line Formula. Eng. Rec.*, June 8, 1894.

—— —— **Valve.** *Note on a Pneumatic Balanced ——.* As used on the Imperial Railways of Japan. By John McDonald. *Proc. Inst. C. E.*, Vol. 117.

Smelting. *Electric —— in Germany.* Description of the methods used and discussion of their possibilities. *Eng. News*, July 12, 1894.

—— **of Silver-Lead.** *The American Practice of Silver-Lead Smelting.* Illustrated. By Walter Renton Ingalls. *Eng. Mag.*, March, 1894.

Smoke Absorption. *The Dylier System.* Illustrated. *Eng. Rec.*, May 12, 1894.

Smoke. *Appliances for Preventing ——.* A series of articles by W. F. Sicard. *Mech. World*, Aug. 10, 1894, *et seq.*

—— *Consumer.* A new system applied to furnaces, boilers and domestic heaters. A long article, illustrated by 51 cuts, explaining a method of obtaining a rational and complete combustion of fuel. Jh. Hinstin. *Méms. Soc. Ing. Cir.*, July, 1894.

——. *The Heating Power of ——.* Shown to be very small. By R. R. Tatlock. *E. & M. Journal*, Aug. 18, 1894. *Prac. Engr.*, Sept. 14, 1894. *Sci Am. Sup.*, Sept. 29, 1894. *Lon. Engineer*, Oct. 12, 1894. *Am. Eng. & R. R. Jour.*, Oct., 1894.

——. *The Practical Prevention of —— in Boiler Firing by the Use of Producer Gas.* Paper in which William Hutton Blauvelt advances producer gas as an economical and satisfactory fuel for firing boilers. *Proc. Eng. Soc. W. Pa.*, May, 1894.

Smokestack. See *Locomotive* and *Chimneys.*

Soaring Flight. Discussion. By Carl Myers, De Volson Wood, I. P. Church and J. B. Johnson. *Aeronautics*, March, 1894.

——. Interesting articles on ——, by J. Bretonniere, C.E., Wm. Kress, E. C. Huffaker, C.E., Ch. De Louvrie and others. *Aeronautics*, June, 1894.

——. *The "Internal Work of the Wind."* By Prof. S. W. P. Langley, with theory of the soaring of birds. *Smithsonian Publications*, also *Aeronautics*, Jan., 1894.

Solarometer. *The ——.* Description of the new instrument constructed by Lieut. W. A. Bechler, U. S. N., for determining latitude, longitude and azimuth. *E. & M. Journal*, Aug. 18, 1894.

Sound. See *Acoustics.*

Specification *Writing.* Lecture of T. Roney Williamson concerning important points to be observed, and giving general working synopsis of specifications. *Am. Arch.*, Sept. 1, 1894.

——. *Electric Subway ——.* As prepared for different kinds of ducts for Baltimore *Eng. Rec.*, Sept. 1, 1894.

——. *Water Tower ——.* As prepared for the Norwood, O., water tower by G. Bouscaren. M. Am. Soc. C. E. *Eng. Rec.*, Sept. 15, 1894.

Specific Heat. See *Heat.*

Speed Recorder. *The Hausshalter ——.* Description of instrument for measuring train speed. *Ry. E. & M.*, Aug., 1894.

Stadia. *A New Prismatic ——.* Description of a prismatic attachment to the objective of a telescope designed to read distances by coincidence instead of by intercept. By Robert H. Richards. *Jour. Assn. Eng. Socs.*, Jan., 1894.

Standards of Measure. An article of considerable historical and some technical import. By Edward P. Clark, E. M. *Columbia Coll. Sch. Mines Quart.*, Jan., 1893, *et seq.*

Stand-Pipe. *Accident to Supply Pipe of Stand-pipe at Bay Shore, L. I.* Correspondence. *Eng. News*, May 24, 1894.

—— —— *Check-valve for ——.* Opened and closed electrically by the engineer at the pumping station. In operation at Washington, Ind. Illustrated. *Eng. Rec.*, April 21, 1894.

——. *Check-valve for ——. Dousman Automatic ——*, operated by the water pressure; spring adjustment for any required pressure; opens automatically when pressure is released. Illustrated. *Eng. Rec.*, April 21, 1894.

——. *Design of a Water Tower.* Height of support, 100 ft.; of tank, 50 ft.; of conical roof, 52 feet. Total height, 198 ft. 6 in. *Eng. Rec.*, Feb. 24, 1894.

Stand-Pipe.—Continued.

————. *Failure of* ——, *East Providence, R. I.* Description and drawings. On September 7, 1893, the wind caused a collapse of the upper portion, which was repaired. On January 19, 1894, the pipe, when two-thirds full, suddenly burst, ice having formed inside. A letter from Geo. H. Leland, Assistant Engineer, is included, describing details of accident. *Eng. Rec.*, Jan. 27, Feb. 3, 1894. *Eng. News*, Jan. 25, Feb. 8, 22, and March 8, 1894.

————. *Failure of* —— *at Peoria, Ill.* Full illustrated description with extracts from specifications. *Eng. Rec.*, April 7 and 14, 1894. *Eng. News*, April 5, 26 and May 10, 1894. *Fire & Water*, April 7, 1894.

————. *Shut-off Valve for*——. *Automatic* ——. Illustrated. *Eng. News*, April 5, 1894.

Stand-Pipes. *Accidents and Failures of* ——. Continuation of articles by Prof. Wm. D. Pence. Illustrated. *Eng. News*, April 5, 1894, *et seq.*

————. *A Mathematical Investigation of Failures of* ——. By E. C. Murphy. *Eng. News*, Aug. 16, 1894.

————. *Expansion of Ice in* ——. Letter from G. W. Pearsons. *Eng. News*, March 22, 1894.

————. *Failures of* ——. Correspondence in regard to leaning tower at Holdredge, Neb. *Eng. News*, May 24, 1894.

————. See *Water Works.*

Status. *The Professional* ——. Alan Macdougall, M. Can. Soc. C. E., voices different sentiments on the question of making that society a close corporation. There is shown an extended disposition to favor the control of engineering practice by the Canadian Society. *Trans. Can. Soc. C. E.*, Oct.-Dec., 1893.

Stay-bolts. *Tests of Screw* ——. Details of different tests compiled for reference. *R. R. Gaz.*, Aug. 24, 1894.

Steam. *Dryness of* ——. A discussion of the various methods used, by W. C. Unwin. *Prac. Engr.*, Sept. 28, 1894, *et seq.*

————. *Dryness of*——, *Determination of*——. Report of a committee of the British Association on the methods used. *Lon. Engineer*, Aug. 24, 1894, *et seq.* Abstract, *Eng. Rec.*, Sept. 22, 1894.

————. *Economical* —— *Compression.* Theoretical discussion. *Am. Mach.*, Aug. 2, 1894.

———— *Generated from Town Refuse.* The adaptability and possibilities of the utilization of the waste products of cities considered at length by T. W. Baker. *Ind. Engr.*, Nov. 24, 1894.

————. *Generation of* —— *by the Use of Waste Heat of Coke Ovens.* An illustrated description of the operation of some Southern plants. *Am. Mfr.*, Feb. 16, 1894.

————. *Influence of* ——. Paper by Gutermuth read before the Society of Engineers at Aix la Chapelle. Very interesting and giving important information regarding this much debated question. *Ztsch. Ver. Ing.*, Dec. 1, 1894.

———— *Jacket. The Theory of the* ——. Current practice discussed by Prof. R. H. Thurston. *Prac. Engr.*, Aug. 10, 1894, *et seq.*

————. *Measurement of* ——. An apparatus for measuring and registering the quantities of steam passing through conduits or utilized in steam engines, for measuring and registering the work performed by steam engines. By Franz Seiler, of Germany. *Trans. A. S. M. E.*, 1893.

———— *Engine.*. See *Engine.*

———— *Pipes.* See *Pipes.*

————. *Underground Protection of* ——. Brief description of means employed at Iowa State Agricultural College. Illustrated. *Eng. Rec.*, April 28, 1894.

————. *Producer Gas for Raising* ——. See *Gas.*

———— *Raising.* Paper by J. Holliday before the Manchester Association of Engineers. Gives cost per 1,000 gallons as deduced from experience with Lancashire boilers. Forced draft showed a gain of 10 per cent. over natural draft. *Prac. Engr.*, Nov. 2, 1894. *Mach. World*, Nov. 2, 1894, *et seq.*

———— *Separator.* Manufactured by Jos. De Rycke. Illustrated. *Elec. Eng.*, Nov. 21, 1894.

———— *Superheated* —— *and the Apparatus of L. Uhler.* By M. G. Thoreau. *Mem. Soc. Ing. Civ.*, March, 1892.

Steam.—Continued.

——. *Superheated* ——. The advantages of —— pointed out by Prof. W. Cawthorne Unwin. *Cassier*, Nov., 1894.

——. *Superheated* ——. *Experiments with* ——. The relative consumption of steam and fuel with saturated and superheated steam. Description and results of a series of experiments. *Safety Valve*, Nov. 15, 1894.

—— *The Economical Use of* —— *for Heat and Power.* Correspondence. *Eng. Rec.*, March 24, 1894.

——. *The Surface Condensation of* ——. Account of experiments which led Lieut.-Col. Thomas English to conclude that it is governed by the thermal resistance of the film of water deposited by the condensation. *Proc. Inst. Mech. Eng.*, Feb., 1894.

——. See *Gages, Heating, Indicator, Injector, Locomotives, Locomotors, Pipe, Pressure, Pumps, Saturation Curve, Superheating, Thermal Curves, Turbine.*

Steamboats. *Screw Ferry* ——. Illustrated description of the steamer "Pleasure." *Am. Mach.*, July 12, 1894.

——. See *Jet Propulsion, Screw Propeller.*

Steamship. *The Fall River* —— "*Priscilla.*" Illustrated description. *Eng. News*, May 17, and *Lon. Eng.*, July 13, 1894.

——. *The "Northwest."* General description. *R. R. Gaz.*, July 20, 1894.

——. *The U. S. S. "Vesuvius."* With special reference to her pneumatic battery. Prize essay by Lieut.-Comdr. Seaton Schroeder, U. S. N. *Proc. U. S. N. I.*, 1894.

—— *for Passenger Service.* A well written and beautifully illustrated article by Otto H. Mueller. It treats especially of the coast and river steamers of the United States. *Ztsch. Ver. Ing.*, Dec. 1. 1894, *et seq.*

——. *Notes on Machinery of the New Vessels of the U. S. Navy.* See *Navy.*

——. *The New Cunard Steamers "Campania" and "Lucania."* Illustrated description general dimensions, methods of construction and equipment. *Eng. News*, Nov. 30, 1893. *Sci. Am. Sup.*, Aug. 18, 1894.

——. *The Vibrations of* ——. A paper read by Otto Schlick before the Institute of Naval Engineers. Deduces a formula which, it is claimed, gives reliable results as to the number of vibrations per minute. *Am. Eng. & R. R. Jour.*, June, 1894. *Ztsch. Ver. Ing.*, Sept. 15, 1894.

——. *The Vibrations of* ——. Theoretical discussion of vibrations and resulting stresses, by John H. McAlpine and H. C. Flood. *Lon. Eng.*, July 13, 1894.

——. See *Battleship, Cruiser, Ironclad, Machinery, Engine, Marine and Naval Engineering, Navy, Propeller.*

Steel. *Bessemer Process as Conducted in Sweden.* A paper of some interest by Prof. Richard Akerman, of Stockholm, read at the International Engineering Congress at Chicago. *Trans. A. I. M. E.*, 1893.

—— *Crucible* ——. Its early history given by R. A. Hadfield. *The Practical Engineer*, Aug. 31, 1894.

——. *Effect of Hardening on the Ultimate Strength of* ——. A thesis by Mr. Elmer J. Bucknell, of the Rensselaer Polytechnic Institute, giving the results of about eighty experiments on the tempering of tool steel in cold water, boiling water and oil. Boiling water and oil gave the greater elastic limit and ultimate strength, while cold water gave greater hardness. *Eng. News*, Dec. 7, 1893.

—— *Forgings.* Methods advocated to secure efficient and economical handling of the ingot and of subsequent processes in securing the desired product. George M. Sinclair. *Eng. News*, Dec. 13, 1894. *Am. Mach.*, Dec. 6, 1894.

——. *Influence of Chemical Agents on Iron and* ——. Abstract of a paper read before the Association of Engineers of Manchester, England, by Wm. Thomson, F.R.S.E. *Power*, May, 1894.

——. *Note on the Ore Process of Making Steel in a Siemens-Martin Furnace.* By M. A. Pourcel. An illustrated article describing in detail the process of steel making, using pure pig-iron and pig-iron containing phosphorus. *Mems. Soc. Ing. Civ.*, May, 1891.

Stone. *A Circular Saw for Cutting* ——. Description of a saw at d'Enville, having the circumference of the blade set with diamonds. *Annales des P. & C.*, June, 1894.

————. *Experiments to Determine the Effect of the Bedding upon the Strength of Marble.* Abstract of a paper by Prof. M. A. Howe, read before the Indiana Engineers' Society. A valuable investigation of the effects of different beddings used in testing. Recommends the use of tar board for commercial testing. *Eng. News*, Feb. 15, 1894.

————. *Preservation of.* See *Cleopatra's Needle.*

————. *Production of* —— in *1893. Stone*, July, 1894.

————. *Testing of* ——. *The Effects of Bedding upon the Strength of Marble.* A valuable article with tables of results of tests and illustrations of specimens tested. The tests show the relative values of bedding materials as follows: Tarboard, first; sole leather, second; soft pine, third; sheet lead, fourth; cast iron, fifth Prof. M. A. Howe. *Stone*, March, 1894.

————. See *Building Stone.*

Stop-Valve. *Automatic* —— *for Stand-Pipe.* See *Stand-Pipe Check-Valve.*

Straight-Edges. *The Manufacture of Very Accurate* ——. Illustrated. By F. L. O. Wadsworth. *Jour. Frank. Inst.*, July, 1894. *Am. Mach.*, Aug. 2, 1894.

Street *Department.* Organization and work. See *City Engineer's Office.*

———— *Grades and Intersections.* Factors determining their establishing, with their relative importance, with illustrating examples. William B. Fuller. *Jour. Assn. Eng. Socs.*, Nov., 1894.

Street Improvement *of Boston, 1893.* Résumé of report of the Street Department, Henry H. Carter, Superintendent. *Eng. Rec.*, June 30, 1894.

Streets. Scheme for the beautifying of modern cities. Synopsis of paper by Mr. Plüddemann, Breslau, Germany. Advocates the harmonious instead of purely symmetrical arrangement on streets and parking, the use of slightly curved streets, varying their widths and avoiding triangular intersections. *Deutsche Bztg.*, Jan. 3, 1894.

————. *Marking Lines of* ——. Summary of results of inquiries among engineers in various parts of the country. *Eng. News*, June 7, 1894.

————. See *Electric Lighting, Macadamizing, City Engineer's Office, Pavements, Paving, Roads.*

———— *Cars. Vestibules for* ——. Removable vestibules recently brought out by the J. G. Brill Co. Illustrated. *St. Ry. Jour.*, Dec., 1894.

———— *by Alternating Arc.* Superior advantages of the alternating system not admitted. R. E. Richardson and S. G. Butler. *Elec Rev.*, Sept. 7, 1894.

Street Lighting. *Specifications for Electric* —— *for Toronto, Canada.* By E. H. Keating, M. Am. Soc. C. E. *Eng. News*, Aug. 28, 1894.

————. *The Lighting of the Public Streets and the Cost.* Theoretically and practically discussed by Henri Maréchal. *Elec. Rev.*, Aug. 10, 1894.

Street Lines. *The Marking of* ——. C. M. Broomall, Jr. Am. Soc. C. E., describes the methods used in various cities. *Trans. A. S. C. E.*, July, 1894. *Eng. News*, June 7, 1894.

Street Railway. *Cable Traction.* Recent improvements, illustrated by the Broadway Cable Road of New York City, given by G. W. McNulty. *Eng. News*, Sept. 20, 1894. *R. R. Gaz.*, Sept. 21, 1894. *St. Ry. Gaz.*, Sept. 22, 1894, *et seq. Eng. Rec.*, Sept. 29, 1894, *et seq.*

———— *of the North Hudson County in Hoboken.* The hillside loop line; vertical ascent of about 170 feet in 700 feet horizontal distance; alinement nearly 3,700 feet; limiting grade, $5\frac{1}{2}$ per cent. Illustrated. *Eng. Rec.*, June 2, 1894.

———— *Railway Systems of St. Louis.* Paper by Wm. H. Bryan, describing the power houses, tracks, rolling stock and management of the electric and cable lines. Illustrated. *Eng. Mag.*, Dec., 1894. Abstract, *St. Ry. Gaz.*, Dec. 8, 1894.

————. *The Vienna City* ——. Exhaustive and illustrated article considering the subject from a financial and commercial standpoint. By S. Sonnenschein. *Arch. f. Eisenbw.*, Part 5, 1894.

————. *Third Avenue* ——, *of New York.* A short account of the organization and progress of construction, with a description of the street construction and power station. *St. Ry. Jour.*, Jan., 1894.

———— *Traction.* The commercial possibilities of accumulators considered as a municipal undertaking. Illustrated. Alfred H. Gibbings. *St. Ry. Gaz.*, Dec. 29, 1894.

Surveying.—Continued.

————. *Trigonometrical Leveling and Refraction.* A brief and interesting article. By Prof. W. R. Hoag, C.E., University of Minnesota. *Year Book of Soc. of Engrs.*, 1894, University of Minnesota.

————. See *Geodesy, Base-Lines, Bench-Marks, City Engineer's Office, Coast and Geodetic Survey, Geodesy, Omnimeter, Photography, Precise Levels, Railroad* [illegible], *Stadia, Steel Tapes, Streets.*

————. See *Topography, Tacheometry, Telemeter, Triangulation.*

Suspension Bridges. See *Bridges.*

Swamps. See *River Improvements.*

Switches. See *Railroad Switches* and *Power Plant.*

Syphons. *Inverted Sewer* ——. Description of the syphons and the construction of the line under the Elbe at Madgeburg, Germany. *Eng. Rec.*, Oct. 27, 1894.

Tacheometry. *Practical Observations in* ——. Reginald Empson Middleton gives results of trials which tend to show the accuracy of the "intercept" system greater than that of the tangential system of Wilfred Airy. *Proc. Inst. C. E.*, Vol. 116.

Tangents. See *Railroads.*

Technical Education. See *Education.*

Tehuantepec *Inter-Oceanic Route.* The Advantages of ——. By Elmer L. Corthell. *Eng. Mag.*, Nov., 1894. *R. R. Gaz.*, Dec. 7, 1894.

Telegraph. *New Headquarters of the Postal Telegraph-Cable Co., New York.* Illustrated description of complete plant, building, wire system, pneumatic distribution, etc. *Elec. Rev.*, April 18, 1894.

————. See *Cables.*

Telemeter. *The Stroobants Prism* ——. A small optical instrument for determining approximate distances. *Sci. Am. Sup.*, July 21, 1894.

Telephone *Exchange.* Description of the arrangement of the new exchange of the National Telephone Company in London. *Elec. Rev.*, Nov. 23, 1894.

————. *The Loud Line in* ——. With methods of increasing the efficiency, by A. V. Abbott, Jun. Soc. C. E. *Trans. A. S. C. E.*, July, 1894. *Elec. Rev.*, Sept. 7, 1894.

————. See *Railroad.*

Teredo. *The* —— *Navalis.* The appearance of the marine animal in Boston Harbor in [illegible]. By Henry Manley. *Jour. Assn. Eng. Socs.*, May, 1894.

Terminal Station *of the Brooklyn Bridge.*

Test Borings. See *Lighthouse.*

Test Pieces. *Forms of Tensile* ——. Leonard Hodgson Appleby advocates the use of standard proportions, after showing results differing with varying proportions of length to cross-section. *Proc. Inst. C. E.*, Vol. 118.

Testing Machine *and Tests of Materials.* Illustrated description of the Olsen testing machine and autographic recording device, with examples of diagrams. *Eng. News*, April [illegible], 1894.

————. *A Single-Lever* ——. Paper by J. H. Wicksteed, before the Institution of Mechanical Engineers, describing the construction of a simple testing machine, capacity fifty tons, accurate and easy to calibrate. *Proc. Inst. Mech. Engrs.*, Aug., 1892.

Testing Machines. *Discussion of* ——. Proceedings of the Third Monthly Meeting of the American Society of Mechanical Engineers. *Am. Mach.*, March 22, 1894.

————. *English and American* ——. A series of illustrated articles describing the various machines and appliances used in testing structural materials in England and the United States. *Eng. Rev.*, London, Oct. 20, 1893, *et seq.*

————. *Phœnix Iron Co.'s Two Million Pound Hydraulic* ——. *R. R. Gaz.*, Feb. [illegible], 1894.

————. *Some Improvements in* ——. The subject of discussion at the monthly meeting of the American Society of Mechanical Engineers, held in April. *Am. Eng. & R. R. Jour.*, May, 1894.

————. *The Emery* ——. Full illustrated description, showing details of this extremely accurate machine. *Eng. News*, March 22, 1894.

Testing-Machines.—Continued.

——— *with Automatic Register.* By M. Emile Petit. Description and illustrations of apparatus from 100 kilogrammes capacity to 100 tons. One large plate. *Méms. Soc. Ing. Cir.*, March, 1891.

Tests of Engineering Materials made at the Mass. Inst. Tech., 1887-1894. Complete record of some twelve hundred tests on wrought and cast iron and steel; on wooden beams, wire, etc. *Tech. Quart.*, Vol. VII, July, 1894.

Tests *of Brakeshoes.* See *Brakeshoe Tests.*

——— *of Materials.* General résumé of methods, purposes, and machines used in testing, by Gus C. Henning. *Cassier*, October, 1894.

——— *of Materials for Fire Proofing Columns.* Results of tests by fire and water at Vienna. *Eng. News*, Sept. 6, 1894.

——— *of Rolling Load and of the Action of Shocks*, as affecting structures, with formula for deflection of a girder under a determinate shock, by M. Deshandres. *Annales des P & C.*, June, 1894.

———. *Paving Brick* ——. *Results of* —— *at St. Louis.* By Prof. J. B. Johnson, M. Am. Soc. C. E., Chairman Assn. Eng. Socs.; arranged to indicate comparative values for paving purposes. *Eng. News*, July 26, 1894.

———. *Physical and Mechanical* —— *on the Steam Engines and Machines at the World's Fair.* Report of the committee to consider and report methods and kinds of tests to be employed. No detail of methods are given. *Trans. A. S. M. E.*, Vol. XIV, 1893.

———. *Report of Committee on Standard* —— *and Method of Testing Materials.* Resolutions of the conferences held at Munich, Dresden, Berlin and Vienna relative to uniform methods of procedure in testing building and structural material. Translated by Gus C. Henning. *Trans. A. S. M. E.*

———. *The Resistance of Materials under Impact.* Address of Prof. Mansfield Merriman, giving the history of tests for this purpose, deductions, laws and lines for future investigations. *Proc. Am. Assn. for Advancement of Science*, Vol. XLIII, 1894, and *reprint.*

———. *Microscopic Examination* ——. See *Impact, Iron, Laboratories, Limes and Cements, Locomotive, Nails and Drift Bolts, Piles, Pumps, Pumping Engine, Punching Tests, Steel, Stone, Stresses.*

———. See *Cement, Coal, Concrete, Engines, Eye-bar, Torsion Machine, Torsion Tests, Water.*

Theatre. *Fire Catastrophies in* —— *and their Prevention.* By Wm. Paul Gerhard. *Sci. Am. Sup.*, Oct. 27, 1894, *et seq.* *Jour. N. E. W. W. Assn.*, Dec., 1894.

Thermal Curves. *New Construction of* ——. Article by M. Talle, giving a very interesting description of a new method of construction of the various curves expressed by the formula $pv^x = \text{Const.} = p_1 v_1^x$. *Ztsch. Ver. Ing.*, Dec. 8, 1894.

Trottle Valve. See *Boilers.*

Thrust Blocks. *Surface of* ——. Article by Geo. R. Bate, giving diagram showing surface of thrust blocks per indicated horse-power for various speeds of vessels. *Pract. Engr.*, Nov. 2, 1894.

Tie Plates. *The Value of* —— *in Track Repairs.* An extended analysis of the dimensions, form and functional purpose of tie plates. By Benjamin Reece. Read before the Buffalo Association of Railroad Superintendents, April 19, 1894. *Pamphlet, Q. & C. Co.*, Chicago.

———. See *Railroads.*

Timber *and Tie Preserving Works.* Illustrated description of the works at Las Vegas, N. M., by F. Meredith Jones. *Eng. News*, Sept. 13, 1894.

———. *Preservation of* ——. Lecture by O. Chanute before the students of Rensselaer Polytechnic Institute. *Polyt.*, Nov. 29, 1890.

———. *Preservation of* ——. See *Wood. Railroad.*

——— *Preservation. Results of* —— *by the Wellhouse Process.* Number of ties treated by this zinc-tannin process, and results obtained. By O. Chanute, M. Am. Soc. C. E., M. Western Soc. Engrs. *Eng. News*, June 28, 1894.

——— *Tests.* See *Wooden Beams* and *Tests.*

Water Purification.—Continued.

————. *The Warren Mechanical Filter*, as used at Athens and Macon, Ga.; Decatur, Ills., and other places. *Eng. News*, Jan. 4, 1894.

Water Supply and the purification of water, with especial reference to intermittent sand filtration. By Wynkoop Kiersted. *Jour. Assn. Eng. Socs.*, Jan., 1894.

————. The Water Works Plant of the city of Berlin, Germany. A description of the Berlin water works from 1853 to date, giving an account of construction, cost and capacity. Synopsis of paper read by Mr. Beer before the Architectural Club of Berlin. *Deutsche Btzg.*, Jan. 3 and 6, 1894.

————. *A Consideration of Artesian Well and Surface Waters from the Standpoint of Bacteriology and Public Health.* A paper read before the New Jersey Sanitary Association by T. M. Cheesman, M.D., Instructor in Bacteriology, Columbia College, New York. A careful presentation of the subject, with valuable conclusions. *Eng. Rec.*, Jan. 6, 1894.

————. *A Description of the Underground* —— for the city of Dresden, Germany, giving an account of the geological conditions there existing, and of the results obtained from a number of wells sunk for experimental purposes; also the effect of the Elbe river on the quality and quantity of the supply. *Jour. f. Gasb. u. Wasserv.*, Jan. 1 and 10, 1894.

———— *and Sewage Disposal in Large European Cities.* By J. S. Billings. *Eng. Rec.*, Nov. 10, 1894.

———— *and Water Power of Austin, Texas.* Abstracts from the annual reports of W. J. Oliphant, Secretary of the Board of Public Works. *Eng. News*, Jan. 25, 1894.

————. *City —— of the Future.* An article of general interest, touching on the employment of salt water except for drinking. By Samuel McElroy, C.E. *Eng. Mag.*, March, 1894.

————. *Driven Wells of Brooklyn.* A paper read before the Milwaukee Convention of American Water Works Association, by Samuel McElroy. Illustrated. *Proc. Am. W. W. Assn.*, 1893.

————*for Indian Towns.* With amount consumed and needed. By C. S. R. Palmer. *Ind. Eng.*, July 7, 1894.

————. *Free* ——. The plan proposed by Hon. Horzen S. Pingree, Mayor of Detroit, Mich., with his arguments in favor of it. Also lengthy editorial comment on the same. *Eng. News*, Jan. 25, 1894.

———— *in the Fire Department.* Experiences in Detroit, Mich., where the department is charged with the water supply for its own uses. James E. Tryon. *Jour. N. E. W. W. Assn.*, Dec., 1894.

———— *of Waltham, Mass.* Illustrated. *Jour. N. E. W. W. Assn.*, March, 1894.

———— *of Pittsburg and Allegheny City, Pa.* By James H. Harlow, C. E. Also a paper by Gustav Kaufman, proposing a method of natural filtration of river water for domestic use. *Proc. Eng. Soc. W. Pa.*, 1893.

———— *of Saginaw, Mich.* Description. *Eng. News*, May 31, 1894.

———— *of the City of Rome.* A discussion of the II books of Frontinus on the water supply of the ancient city, and a study of the old aqueducts. By Clemens Herschel. *Trans. Assn. Engineers of Cornell University*, 1894.

———— *of Toronto.* E. B. Shuttleworth discusses the bacteriological condition of Toronto's Lake Ontario water. *Eng. News*, Oct. 4, 1894.

———— *of Various European Cities.* Sources, works and systems, with copious comments and valuable suggestions. Allen Hagen. *Jour. N. E. W. W. Assn.*, Dec., 1894.

———— *of Wisconsin.* Its geology; valuable tables given. Paper by D. W. Mead, C.E., for the American Water Works Convention at Milwaukee. *Proc. Am. W. W. Assn.*, 1893.

———— *of Zurich.* See *Electric Works.*

———— *at Alliance, O.* Described and illustrated. *Eng. News*, June 14, 1894.

————. *On Artesian Wells as a Source of* ——. A paper read before the American Water Works Convention at Milwaukee, by Prof. Erastus G. Smith. Illustrated. *Proc. Am. W. W. Assn.*, 1893. *Sci. Am. Sup.*, Jan. 27, 1894.

————. *Plainfield, N. Y., —— System. Driven Wells of the* ——. Fully illustrated description and valuable data. By L. L. Tribus. *Trans. A. S. C. E.*, March, 1894. Abstract, *Eng. News*, Feb. 22, 1894.

Water Works.—Continued.

——. *New Pumping Engines for the Chicago* ——. General description, with specification requirements. *Eng. News*, Sept. 20, 1894.

——. *Notes from Recent Reports of Water Works. Eng. News*, March 22, 1894.

—— *of Atlanta, Ga.* Full illustrated description. *Eng. Rec.*, March 31, 1894.

—— *of Denver, Colorado.* Full illustrated description. Pipes of wooden staves largely used, also some cement concrete pipe. Filter plant and reservoirs briefly described. By James D. Schuyler. Discussion. *Trans. A. S. C. E.*, Feb., 1894.

—— *of Fort Worth, Texas.* Full illustrated description. *Eng. Rec.*, June 2, 1894.

—— *of Nashville, Tenn.* General illustrated description. Supply usually drawn from filter galleries on the banks of the Cumberland River. *Eng. Rec.*, Oct. 6, 1894.

—— *of Remscheid, Germany.* General description of masonry dam, of about 80 feet height. *Eng. Rec.*, Sept. 8, 1894.

—— *of Sing Sing, N. Y.* General description of source of supply, reservoirs, force-main and pumping station. *Eng. Rec.*, Oct. 27, 1894.

—— *of Syracuse, New York.* Methods of opening the trenches and details of the laying of the thirty-inch conduit from Skaneateles Lake to the city. Thos. McE. Vickers. Illustrated. *Eng. News*, Dec. 13, 1894.

—— *of Syracuse, New York.* Previous water-works of the city, with description of the new system and details of construction and operation. *Eng. Rec.*, Dec. 1, *et seq.*

—— *of the City of Landshut.* The water is filtered and the article describes the sand-filters in detail. Well illustrated and fully described by Ehrlich. *Jour. f. Gasb. u. Wasserv.*, Oct. 10, 1894.

—— *of Various Important Cities.* Well illustrated and briefly described. Illustrations of pumping stations, stand-pipes and construction. Very interesting. *Fire and Water*, June 9, 1894.

——. *Pipe Laying.* A very difficult job of replacing a 6-inch pipe with a 16-inch main across a mill stream, below a dam, under a flume 30 feet wide, and under the wing of a dam. From *Jour. N. E. W. W. Assn. Eng. Rec.*, June 23, 1894.

——. *Proposed Requirements of Water Meters.* Lecture by W. H. Lindley before the German Society of Sanitary Engineers, giving the results of various experiments, with six different water-meters and drawing conclusions therefrom. *Jour. f. Gasb. u. Wasserv.*, Dec. 10, 1894.

——. *Pumping Station.* Article by C. Budil, describing the new pumps and engines recently erected in Königliche Weinberge. The article is well illustrated and describes a thoroughly modern plant. *Ztsch. Ver. Ing.*, Nov. 17, 1894.

——. *Recording the Location of Water Mains.* A method of ——. By Geo. A. Kimball, C.E. *Jour. N. E. W. W. Assn.*, March, 1894.

—— *Records.* See *City Engineer.*

——. *Scrapers for Cleaning Corroded Water Mains.* Illustrated description of types of scrapers. *Eng. News*, Aug. 2, 1894. *Eng. Rec.*, July 28, 1894. *Ry. Rev.*, Aug. 18, 1894.

——. *Some Experiments on the Effect of Water Hammer.* Discussion and statement of results. By Prof. R. C. Carpenter. *Eng. Rec.*, Aug. 11, 1894.

——. *Submerged Intake and Strainer at Burlington, Vt.* Described and illustrated. *Eng. News*, June 21, 1894.

—— *Supply Main of* —— *of Galveston, Texas.* Short article on the determination of its size. By Wynkoop Kiersted. *Selected papers of Rensselaer Soc. Engrs.*, Jan., 1894.

——. *Supply of City of Mexico.* On the distribution of water in the City of Mexico. By R. Salazar, Member Associated Engineers and Architects, of Mexico, at the International Engineering Congress at Chicago. *Trans. Am. Soc. C. E.*, Nov., 1893.

——. *The Boston* ——. Report of the Water Board of Boston for 1893. Abstracted. *Eng. Rec.*, July 21, 1894.

——. *The Glasgow* ——. Illustrated description of the Craigmaddie Reservoir, with detailed account of the pumping engines and other machinery. *Lon. Eng.*, June 1, 1894, *et seq.*

——. *The Manchester Thirlmere* ——. Description of previous water supplies for the city, and of the ninety-five mile conduit from the source of supply at Thirlmere, with other details of the system. *Lon. Engineer*, Oct. 19, 1894. *Ind. Engr.*, Nov. 17, 1894.

Wind Motors, *Ancient and Modern.* By Sidney H. Hollands. *Prac. Eng.*, July 27, 1894. *Sci. Am. Sup.*, Sept. 1, 1894.

Wind Pressure. Abstract of a paper by Prof. Kernot, of Melbourne University. Results of experiments on small sections of various shapes. Recommends that in Australia 20 pounds be taken as the maximum wind pressure upon areas of not less than 300 square feet and 30 pounds for smaller areas. *Eng. Rec.*, Feb. 10, 1894.

Wire Rod. *Rolling* ——. Illustrated, historical and descriptive article by Robert W. Hunt, M. Am. Soc. M. E. *Cassier*, July, 1894.

Wire Rope Tramways. An interesting descriptive article, freely illustrated. By Wm. Heitt. *Eng. Mag.*, April, 1894.

Wires. See *Conduit, Electric Conduits, Glass, Machine.*

Wood. *Preservation of* ——. Illustrated description of creosoting works of Ricker & Lee Galveston, Texas. *Eng. News*, April 12, 1894.

————. *Preservation of* —— Translated from the *Revue Technique. Eng. Rec.*, April 28, 1894, *et seq.*

————. See *Pavements.*

Wooden Beams. Tests of —— made at Mass. Inst. Tech., on spruce, hemlock, white pine, yellow pine and oak beams, of commercial sizes. Also time tests on wooden beams (see *Time Tests*). Full records given of each of several hundred tests. *Tech. Quart.*, Vol. VII, July, 1894.

Wooden Columns. *A Proposed Formula for White Pine Posts*, with tables of safe loads in pounds for yellow pine and for white pine struts. Results of a large number of tests. By James H. Stanwood, S.B., Instructor in Civil Engineering, Massachusetts Institute of Technology. *R. R. Gaz.*, Jan. 19, 1894. *Tech. Quart.*, April, 1894.

Workshops. *Collection of Dust in* —— *and Flouring Mills.* An illustrated paper relating chiefly to the "Prinz Collector." By R. Kohfahl, Hamburg, Germany. *Trans. A. S. M. E.*, 1893.

————. *Lighting of* ——. Electric arc lamp with inverted cone reflector recommended. Illustrated. By B. A. Dobson. *Proc. Inst. Mech. Engrs.*, Oct., 1893.

World's Fair. *An English View of* ——. A popular article by J. Stephen Jeans. *Eng. Mag.*, Dec , 1893.

————. *Cost and Income of the* ——. Cost of buildings and of different departments, etc. Tabulated by Anthon F. Seeberger. Short article. *Eng. Mag.*, Jan., 1894.

————. *Designers and Organizers of the* ——. By E. C. Shankland, C.E , Chief of Engineers of Fair. *Eng. Mag.*, Jan., 1894.

————. *The Architectural Event of our Times.* A popular article by Henry Van Brunt. *Eng. Mag.*, Jan., 1894.

————. *The* —— *and the Railroads.* An interesting and popular article by Col. H. G. Prout. *Eng. Mag.*, Jan., 1894.

Wreck. *Destruction of a* ——. Description by M. de Joly of the removal of the wreck of the steamship "Lizzie" in the bay of Saint-Nazaire. *Annales des P. & C.*, July, 1894.

Wrought Iron. *Structural Changes in* ——. Howard Stillman suggests twisting as a means of producing the molecular crystallization of iron and increasing its tensile strength. *The Prac. Engr.*, June 22, 1894.

Yards. See *Railway Switching, Yards and Railroads.*

Zinc. A popular article on the —— mines of Missouri by H. S. Wickes. *Eng. Mag.*, Feb., 1894.

————. *Manufacture of the Oxide of* ——. Illustrated and described. *Sci. Am. Sup.*, July 14, 1894.

————. See *Lead.*

4